SANFORD UNDERGROUND RESEARCH FACILITY
SOUTH DAKOTA SCIENCE AND TECHNOLOGY AUTHORITY

SURF Underground Access Technical Specification

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1.0 Introduction & Background

The Yates and the Ross Shafts are the two shafts which are used for accessing the underground lab at SURF. Each shaft can access multiple levels within the facility; however, the primary destination are the Science campuses located at the 4850L. This document defines the current operating parameters from which planning for construction and operation of current and future labs can be performed.

MSHA Code 30 CFR § 57.11050 requires two separate, properly maintained escapeways to the surface from UG facilities and/or provision for adequate areas of refuge on occupied levels. The combination of the Ross and Yates shafts/hoisting plants provide the systems required to meet the first part of this code.

The Ross Shaft provides the primary access for the facility dewatering systems, 4850L Ross Campus, and the 4850L LBNF Campus. The Yates Shaft provides the primary access/egress for the 1700L, the 4100L, and the 4850L Davis Campus. Secondary egress can be interchangeable between the two shafts, depending upon the operational needs. Figure 1 illustrates the SURF UG Laboratory Access.

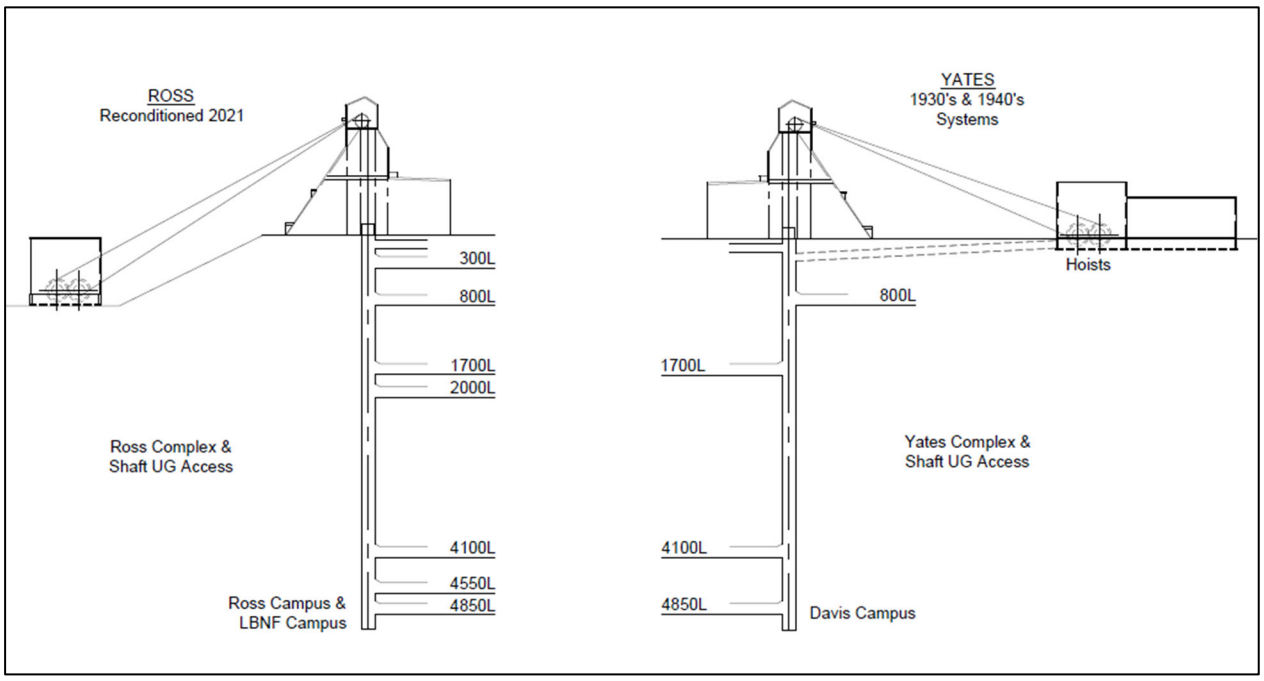


Figure 1: *SURF UG Laboratory Access diagram*

2.0 Ross Shaft

The Ross Shaft is a steel furnished shaft originally constructed in the early 1930's. This shaft has recently been 100% refurbished with new steel sets and ground control.

The Ross Shaft serves as the main access for personnel, materials, and equipment to host construction and operation of the 4850L Ross Campus and the LBNF Campus. The shaft also serves as an accessway for electrical, communication and piping utilities. Although there are existing utilities in the shaft that are necessary for current operation, the design of the new furnishings allows for the support of additional utilities for future operations.

The Ross Shaft also provides access for maintenance to the main pumping stations (laboratory de-watering system) located at the 5000L, 3650L, 2450L and 1250L.

The Ross Shaft is outfitted with a single cage and counterweight arrangement for transport of loads and personnel. Additionally, the Ross Shaft has two identical skips, counter balanced and outfitted to haul waste rock and materials to the surface. The Ross Shaft is the only shaft to be outfitted with skips for waste rock removal as the Yates Shaft skip loading pockets and surface material handling systems are inoperable. Figure 2 illustrates the layout of the Ross Shaft compartments and dimensions.

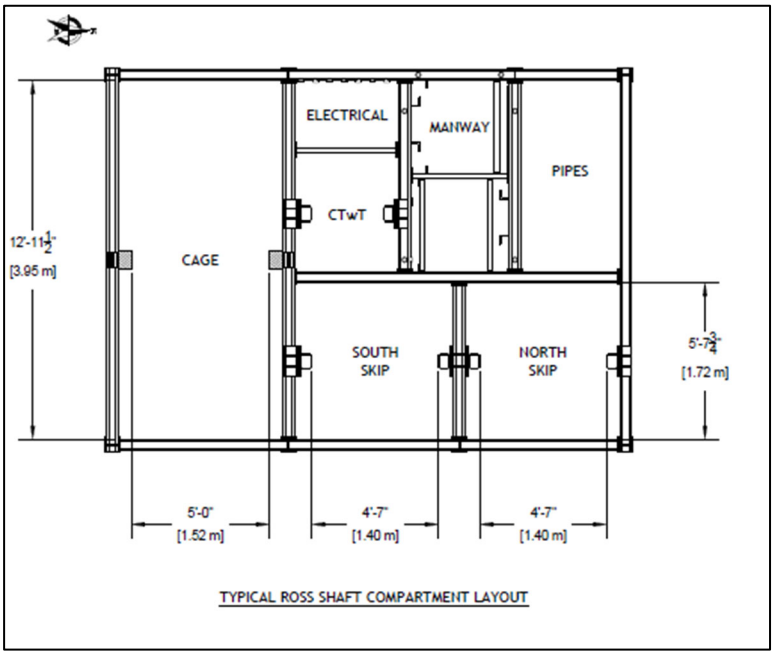


Figure 2: *Ross Shaft typical set general arrangement plan view*

2.1 Ross Conveyances

The Ross conveyances were all replaced as part of the shaft rehabilitation. The Ross conveyances (installed in 2021) consist of the following:

Ross Cage/Counterweight pairing

Ross North Skip

Ross South Skip

The cage conveyance is utilized for the transportation of personnel, materials, and equipment to the underground lab. It operates in counterbalance with a series of weights that are attached to a conveyance that travels in the Counterweight compartment. The Ross Cage consists of an enclosed

personnel/material transport area at the bottom, with a choice to mount either a work deck assembly, or an inspection platform/canopy on the roof for performance of maintenance activities. Loads are also able to be under-slung from the cage using one of the numerous lugs fitted to the cage undercarriage. Figures 3 through 5 illustrate the Ross Cage and appurtenances.

The Ross skip conveyances are used to transport waste rock to the surface. The skips were designed to transport up to 11 tons of rock between the underground skip loading pocket below the 4850L to the headframe rock dump at the surface. The roofs of the skips may be outfitted with a bonnet accessory, thus allowing for authorized personnel to ride the skips for periodic shaft inspection and maintenance. Additionally, the skip bottoms include under-sling lugs for attachment of slung loads. Figure 6 illustrates the Ross skips.

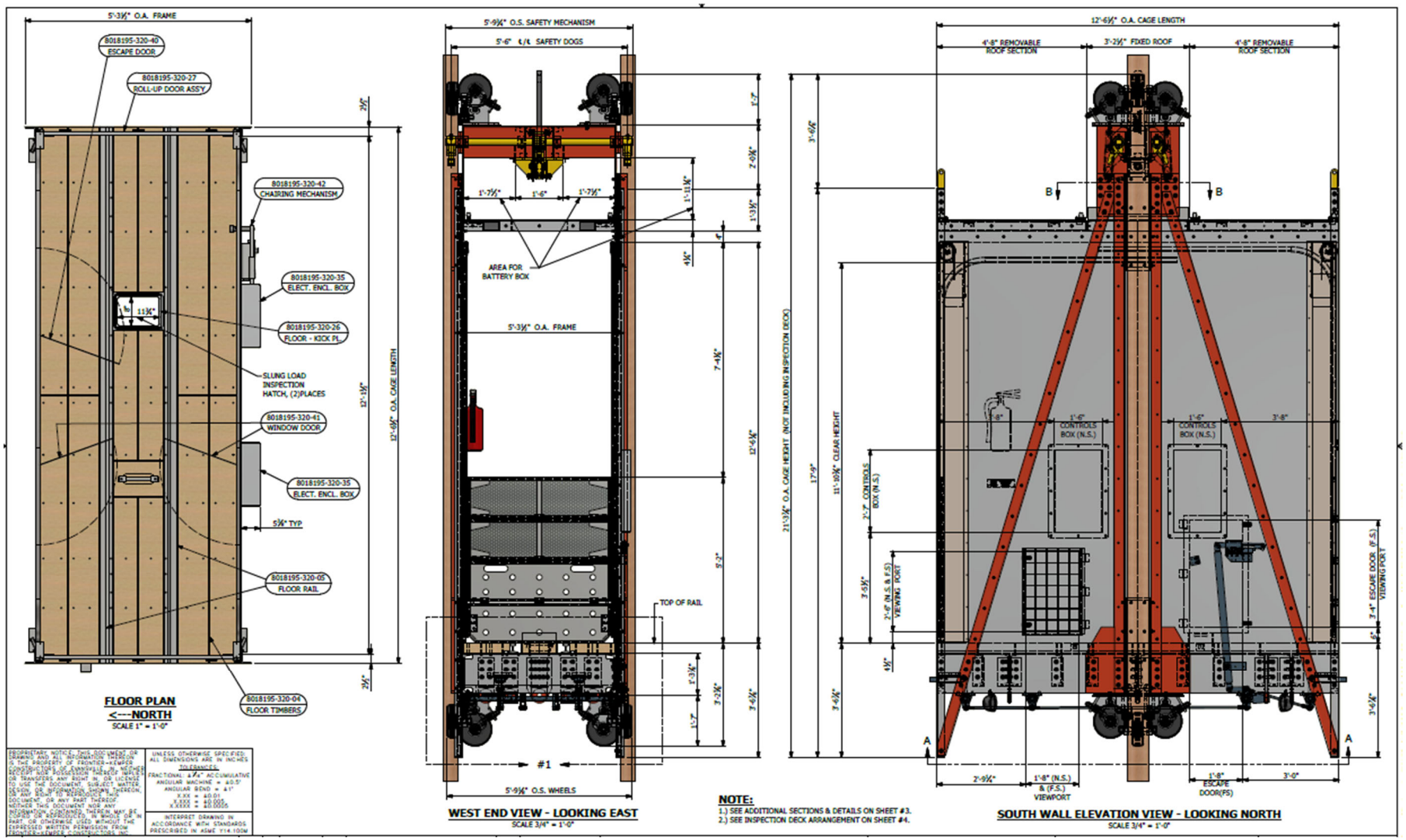


Figure 3: *Ross Shaft single deck cage*

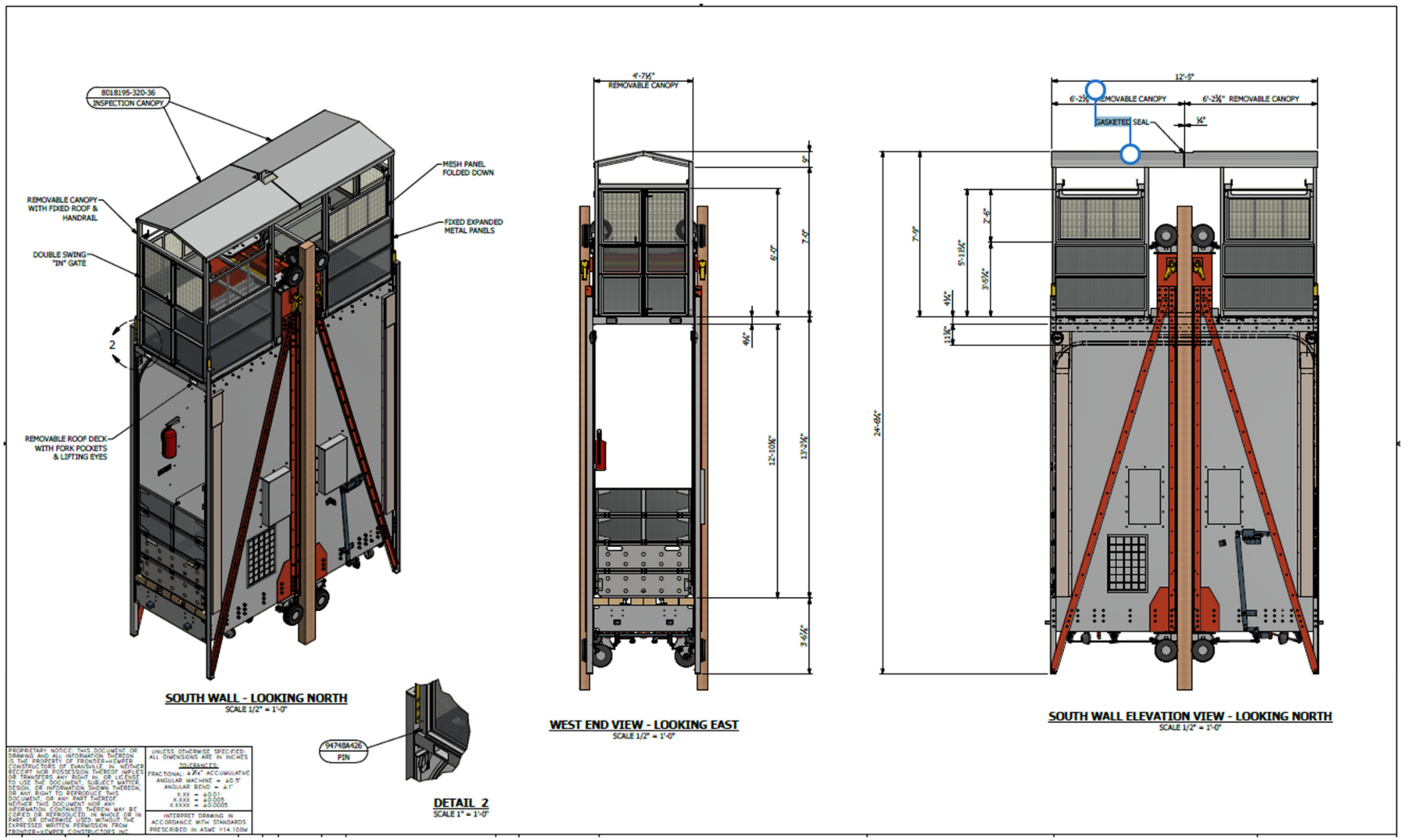


Figure 4: *Ross Shaft single deck cage with inspection platform on top*

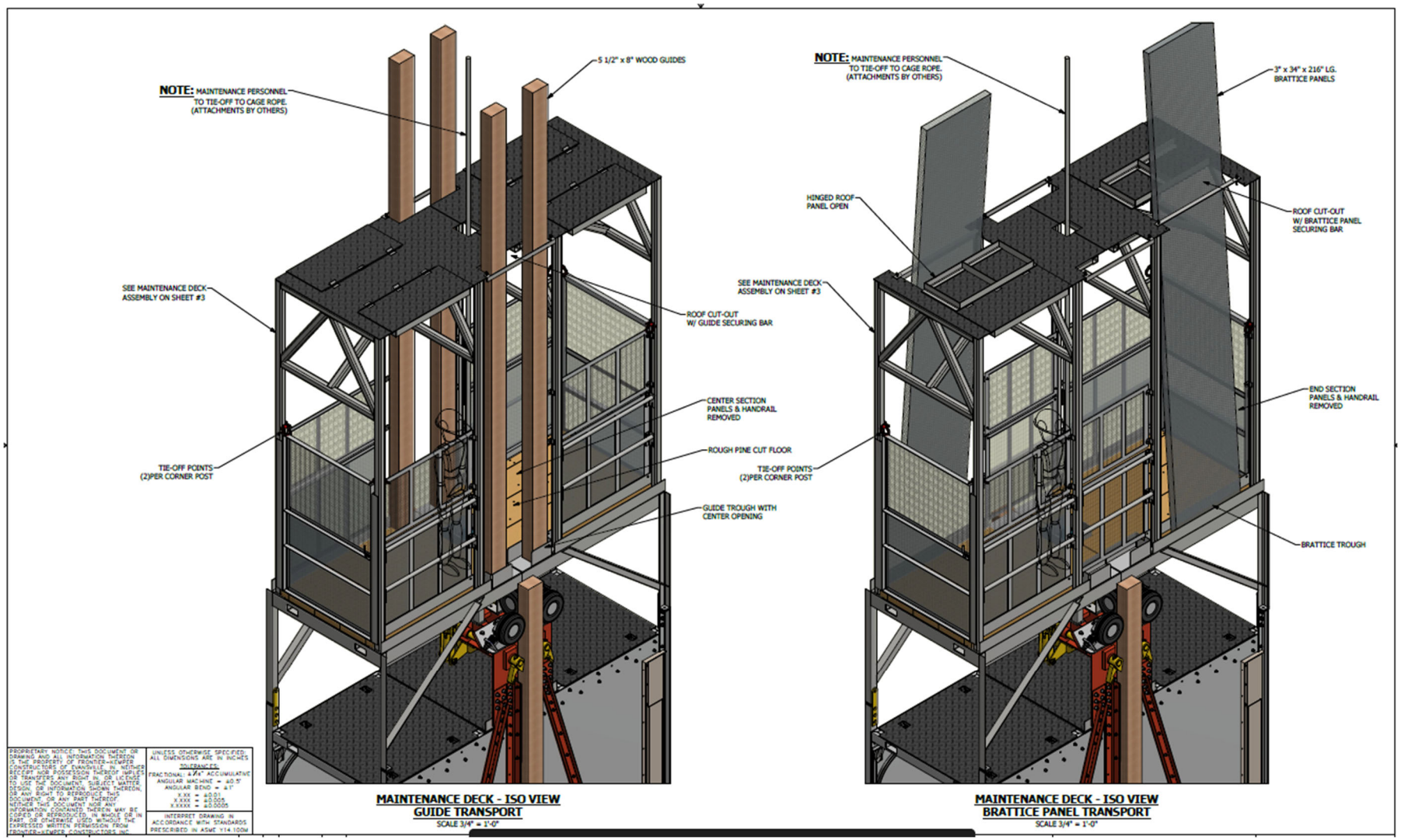


Figure 5: *Ross Shaft single deck cage with maintenance (work deck) platform on top*

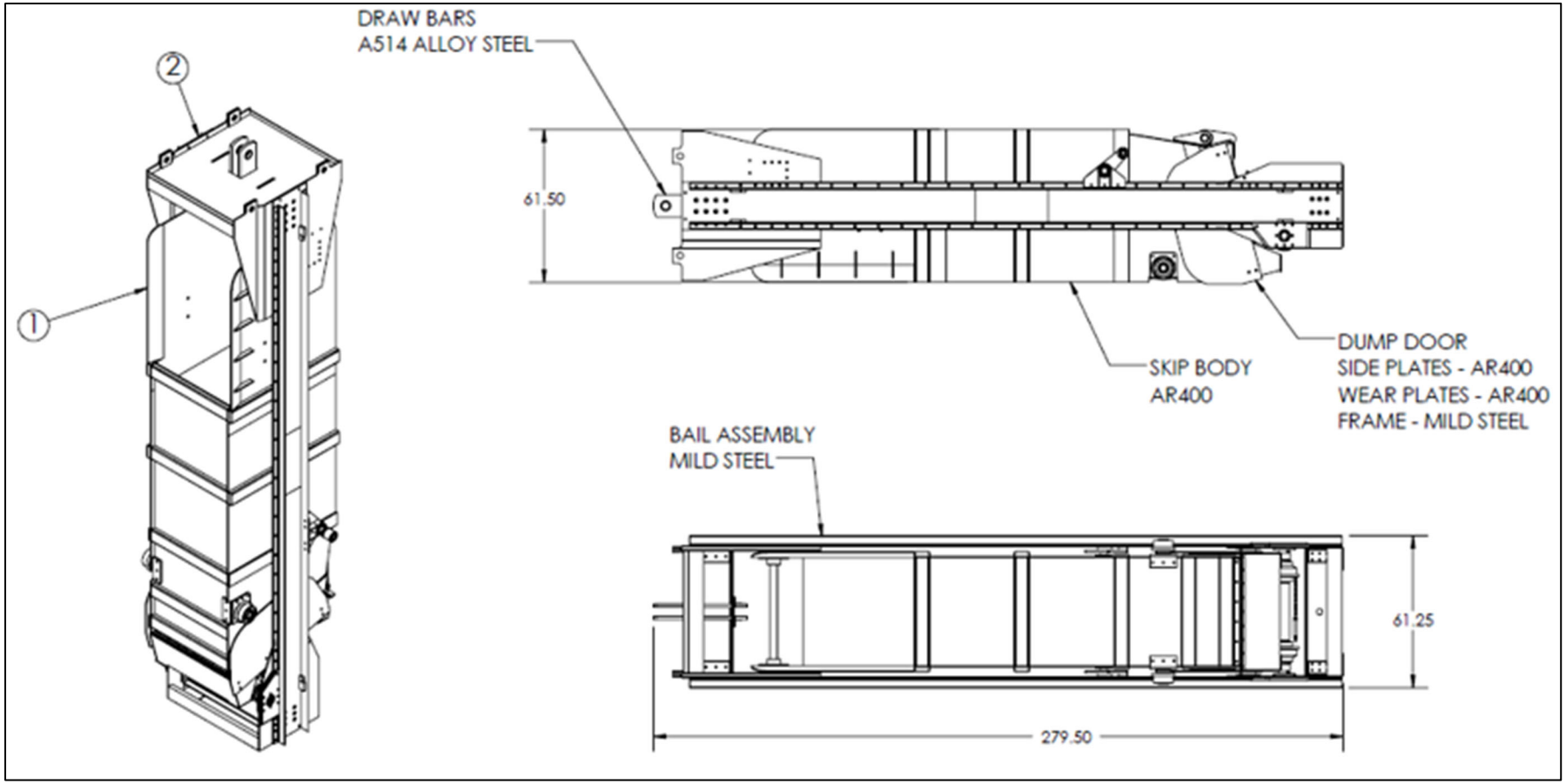


Figure 6: *Ross Skip general arrangement*

The manufactured clear space (no allowance for space around package) in the Ross Cage conveyance is 4 ft 9 in wide x 11 ft 10 7/8 in high x 12 ft 1½ in long with a max payload weight of 13,500 pounds. When planning for material and equipment transport, it is important to include at least 1 in [25.40 mm] of clearance on all sides above the floor, 1 inch in height, and 1 ½ in of length for ease of material handling. **The practical operational space in the Ross Cage conveyance is therefore 4 ft 7 in wide x 11 ft 9 7/8 in high x 12 ft long.** In addition, an allowance of 18 in [457.20 mm] should be included at the bottom of this space for standard rail car on which a container rests that could be rolled in and out of the cage for transportation in the underground drifts. Once on the 4850L, the load would be rolled out of the conveyance on to the station. From that point, it may be necessary to rotate the container to lay horizontally so that it could be more stable while travelling through the access drifts. The unloading of the conveyance on the 4850L using a standard 18-inch-tall rail car is shown in Figure 7 below:

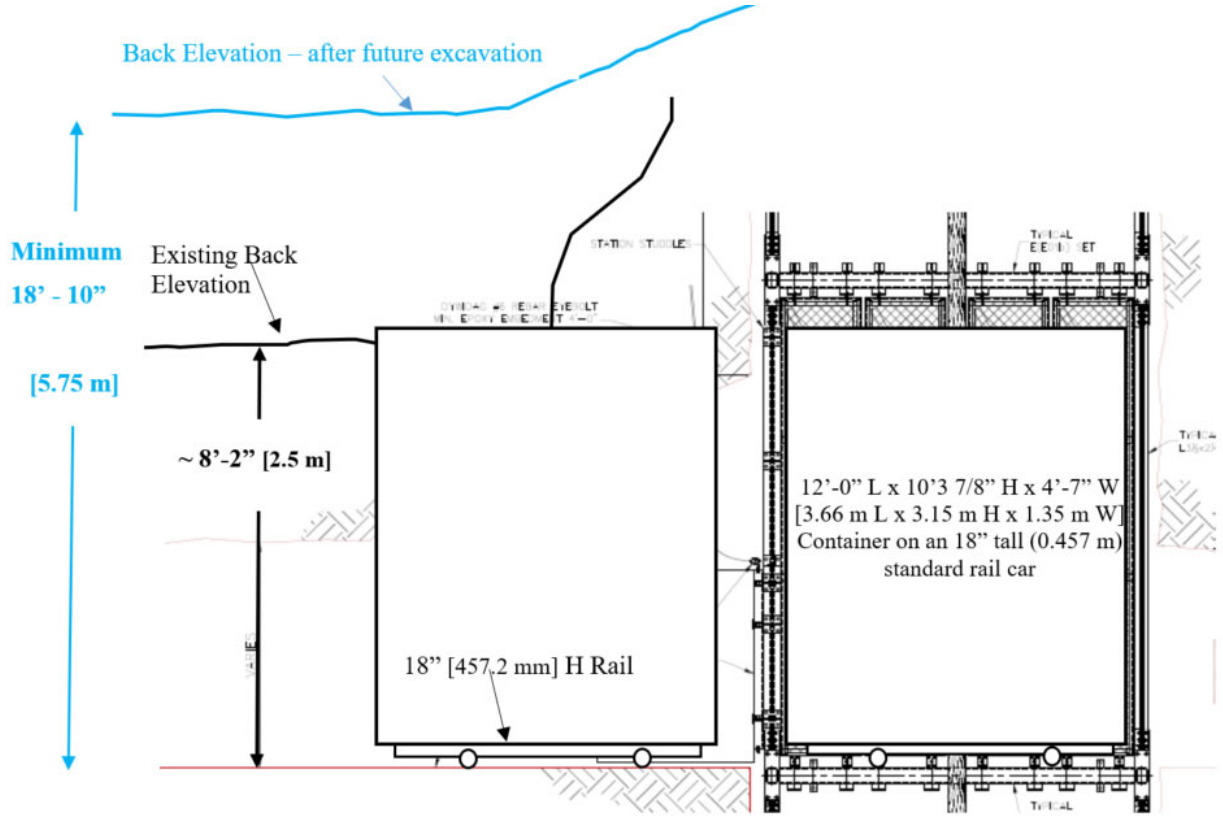


Figure 7: *4850L Ross Station back elevation, cage unloading considerations*

2.2 Ross Shaft Stations

Figure 7 above shows what is possible once the Ross 4850L station is excavated *(currently scheduled for late 2023)* to provide greater clearances to the station back. Figure 8 below provides a more detailed view for the anticipated 4850L Ross brow excavation. There are several issues that will need to be resolved before detailed plans can be made. They are as follows:

- The final height of the 4850L station and Access drift has not been finalized.
- There are also different means of loading equipment into the cage that can be utilized, if necessary, they are summarized in the table below. The maximum height of a component that can be transported using each option is also listed.

Means of moving component into cage	Required Clearance		Max height of component	
	in	*mm*	*Ft*	*mm*
Dragging or use of skid plate	0 - ¼	0 – 6.35	11’ 10 5/8”	3620
Air Bearing	1 ½	38.1	11’ 6 ½”	3518
Lowboy or Rail Cart	8	203.2	11’ 2 7/8”	3426
Standard Car	18	457.2	10’ 3 7/8”	3146

Table 1: *Component haulage clearance and component max height – Ross Cage*

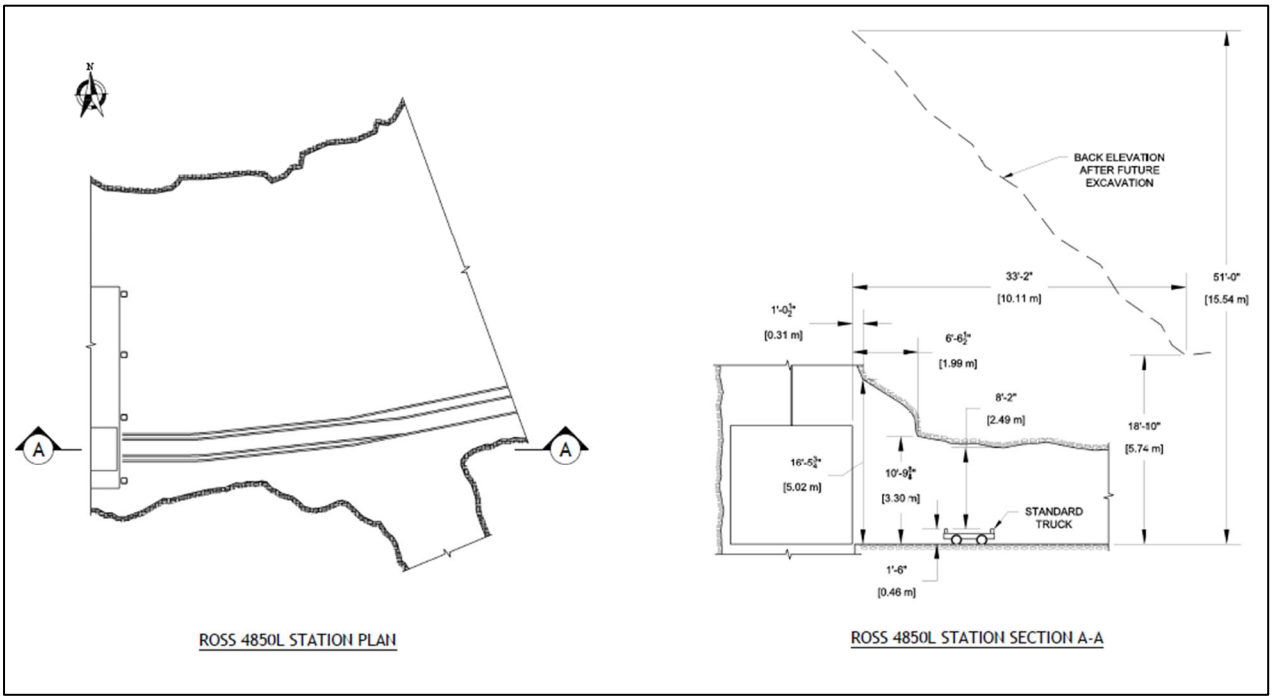


Figure 8: *4850L Ross Station*

Besides the main laboratory areas on the 4850L, there are six other Ross Shaft stations that may have laboratory traffic: the 300L, 800L, 1700L, 2000L, 4100L and the 4550L. Figures 9 through 14 illustrate the brow/drift clearances with respect to the cage for those levels, respectively.

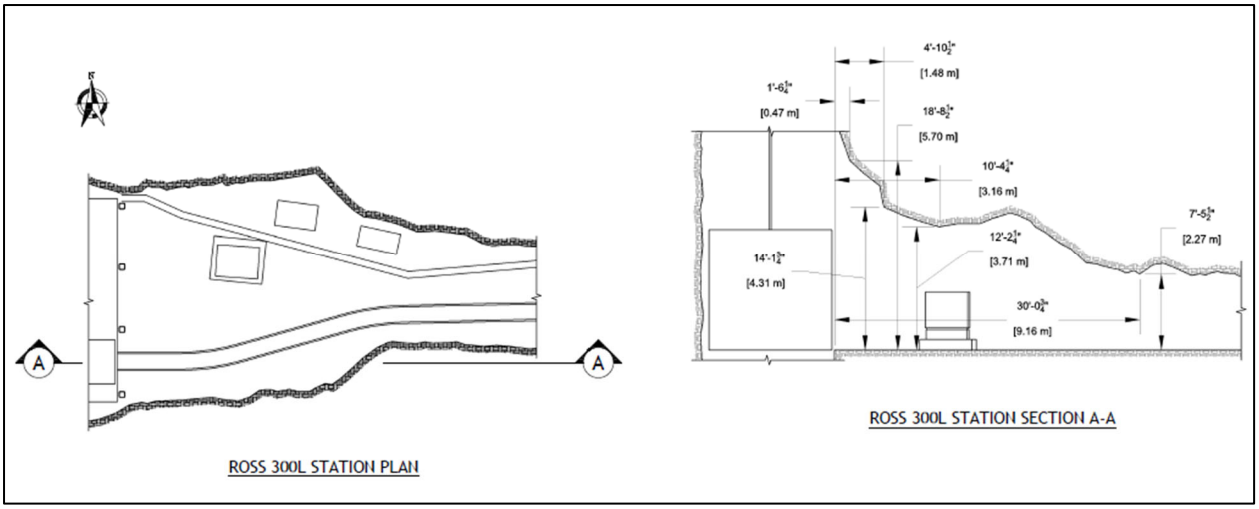


Figure 9: *300L Ross Station*

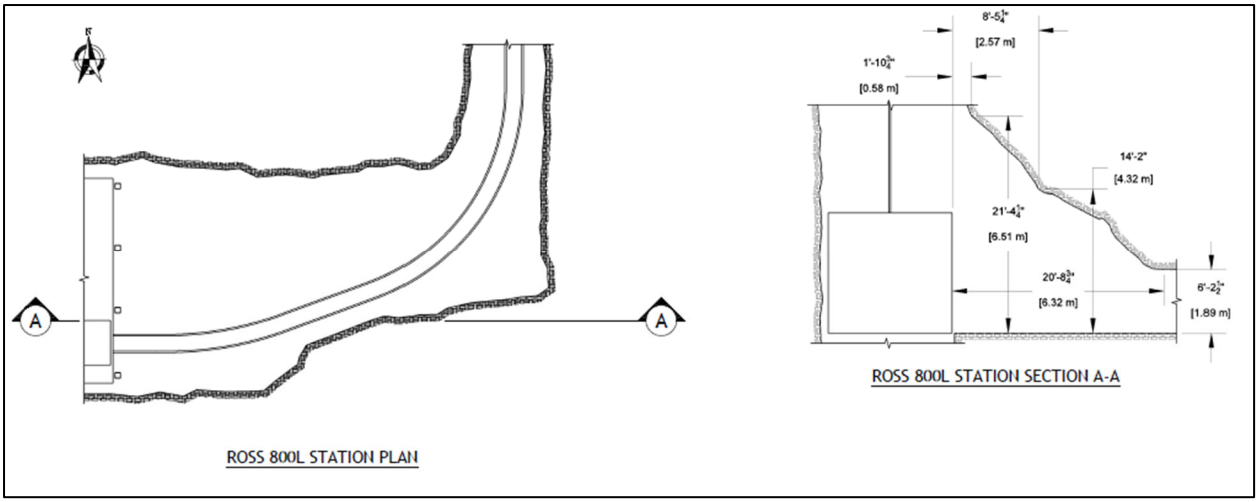


Figure 10: *800L Ross Station*

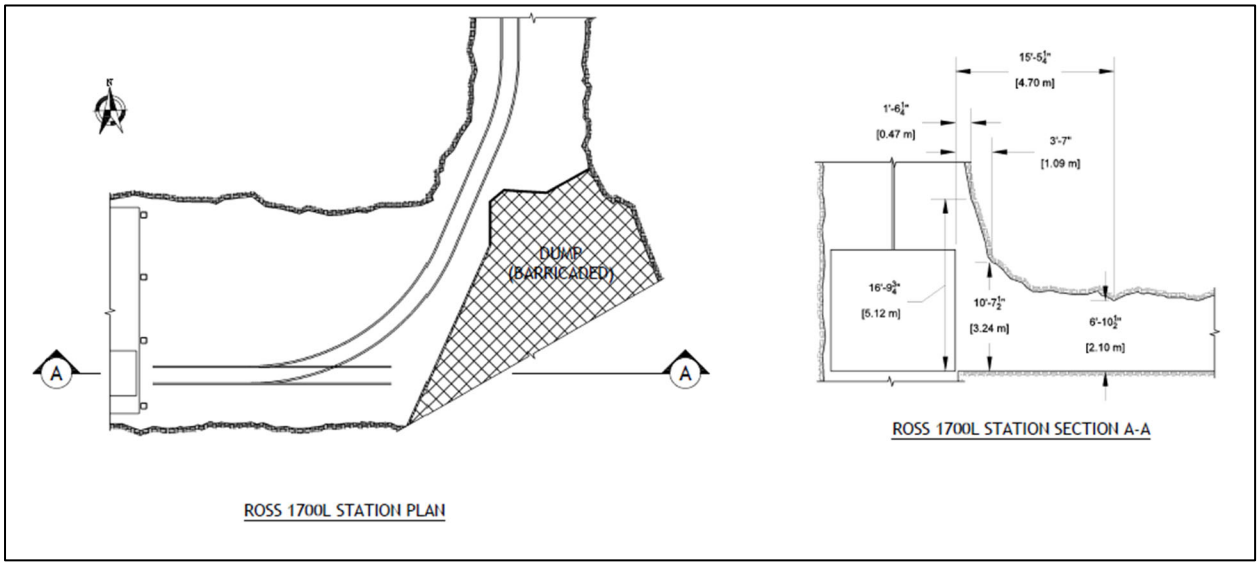


Figure 11: *1700L Ross Station*

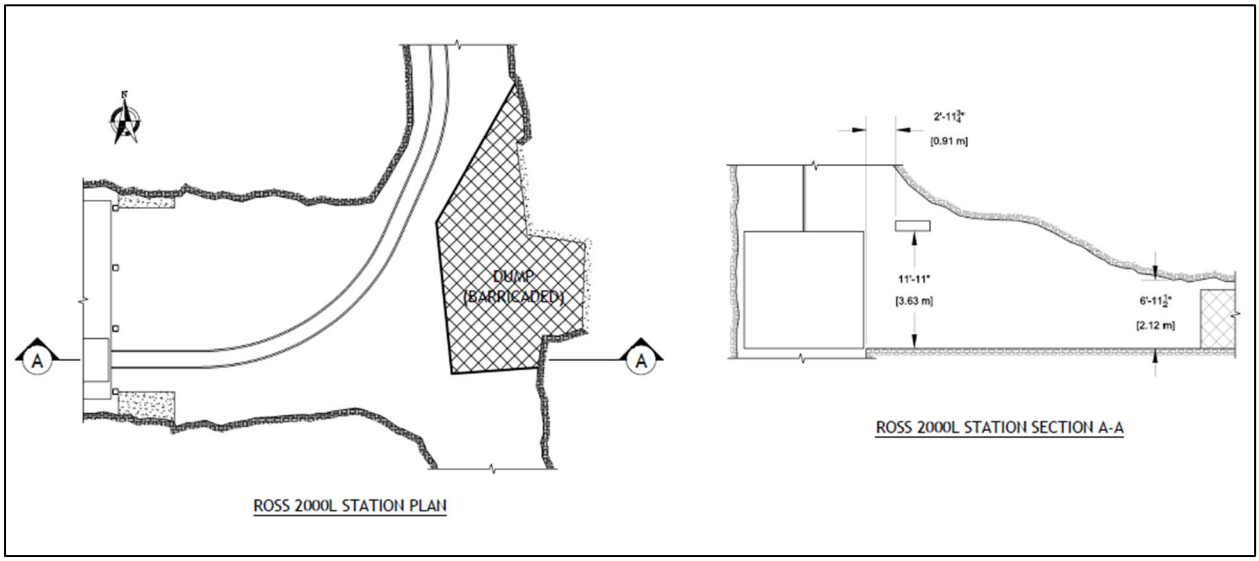


Figure 12: *2000L Ross Station*

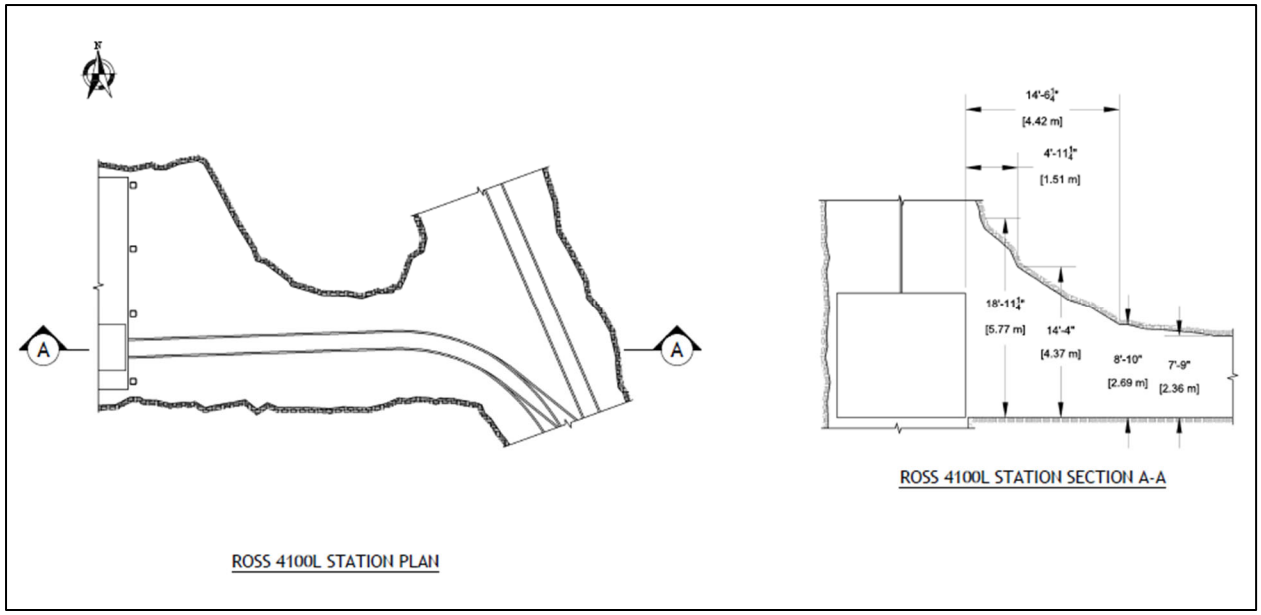


Figure 13: *4100L Ross Station*

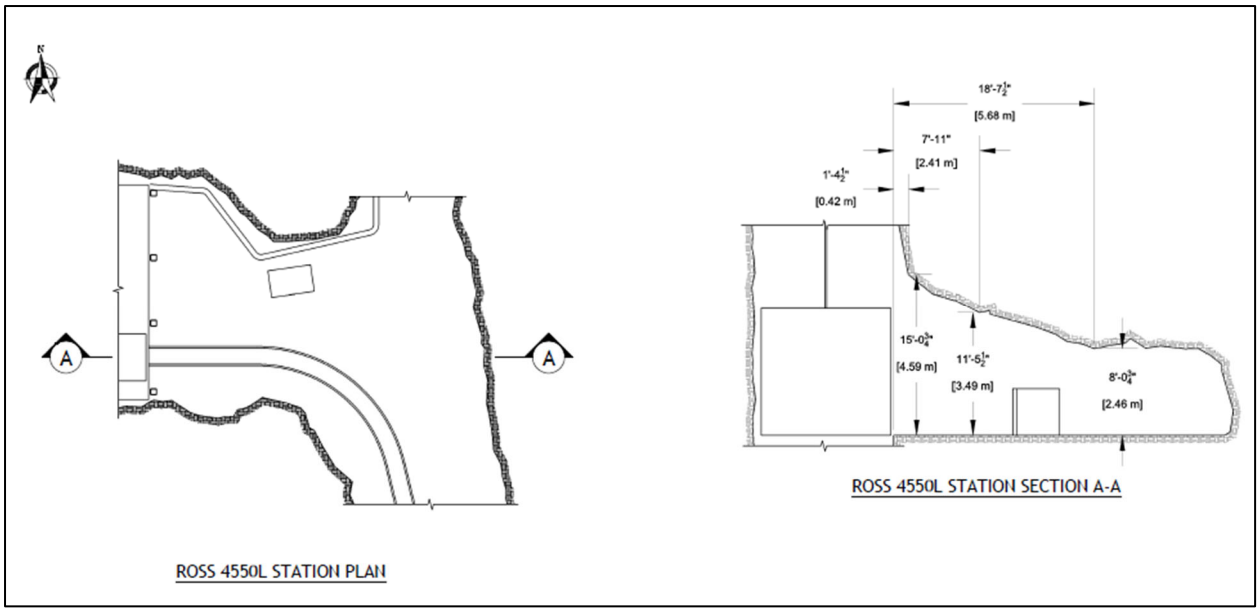


Figure 14: *4550L Ross Station*

2.3 Ross Slung Loads

In some cases, where loads do not fit in a conveyance, loads are conveyed to the underground by suspending them under a conveyance. These are called Slung Loads. In determining whether a load can be slung under a conveyance, there are several factors to consider which include:

1. The load needs to fit within the space available in the compartment with at least 2 in [50.8 mm] clearance on all sides; See Figure 2.
2. There needs to be enough space under the conveyance when the cage is at its highest location in the headframe for the load to be pulled into the compartment from the shaft collar.
3. There needs to be enough space at the unloading location (underground station) for the load to be pulled out of the compartment and on to the level. Note a winch/tugger is positioned at some shaft stations and can be used to help remove the slung load from the shaft. It should be verified for load capacity and presence at the station during the planning process.
4. Typical travel speeds for slung loads are limited to 100 feet per minute [0.508 m/s]. This is typically referred to as creep speed. This can be somewhat controlled in special situations by installing guide shoes on the load. However, this process adds considerable time to the conveying process.
5. The load cannot exceed 13,500 lbs.
6. Slung load plans are to be reviewed/approved through SDSTA Operations prior to implementation.

Figure 15 below illustrates the undercarriage of the Ross Cage and capabilities/location for the under-sling connection points. An analysis has been performed for Slung loads in the Ross Shaft Cage Compartment based on the utilization of the Cage conveyance as shown in the previous graphics. The result of this analysis is shown in the Figure 16.

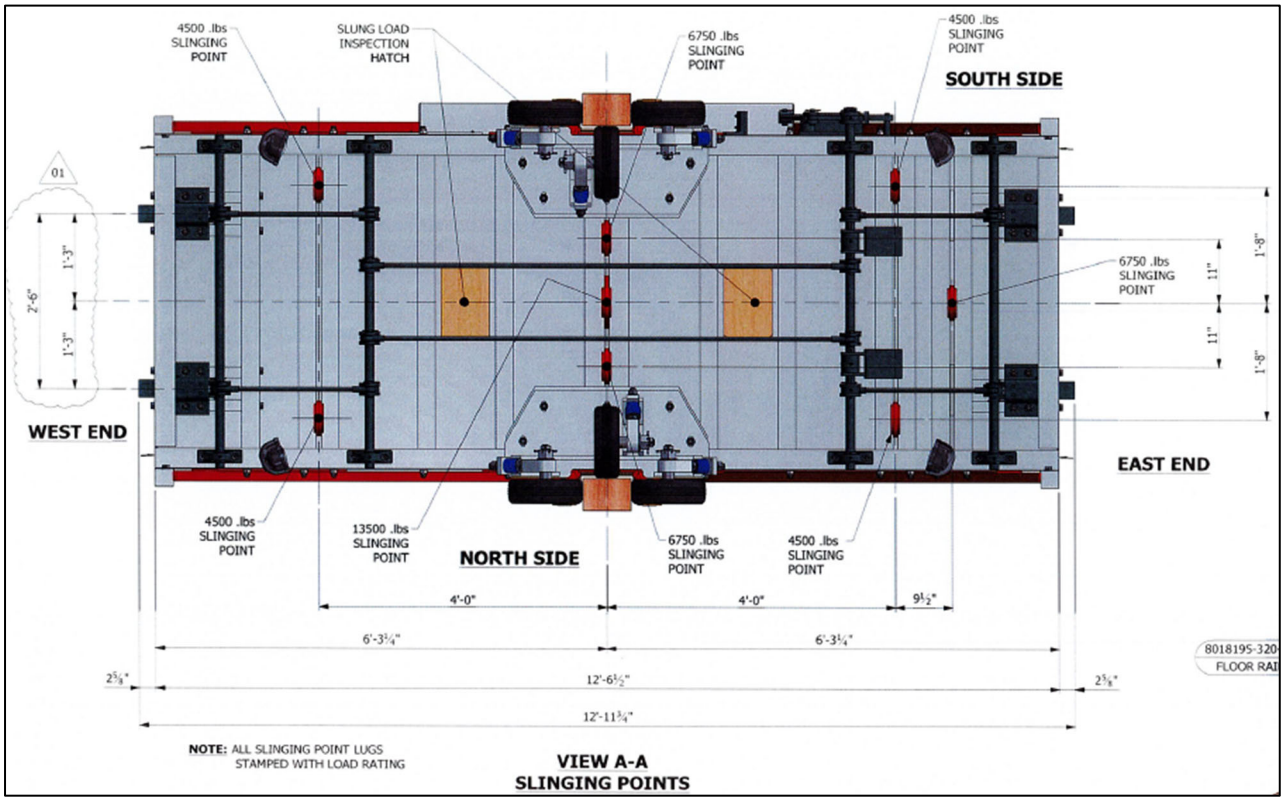


Figure 15: *Ross Cage under-sling connections & location*

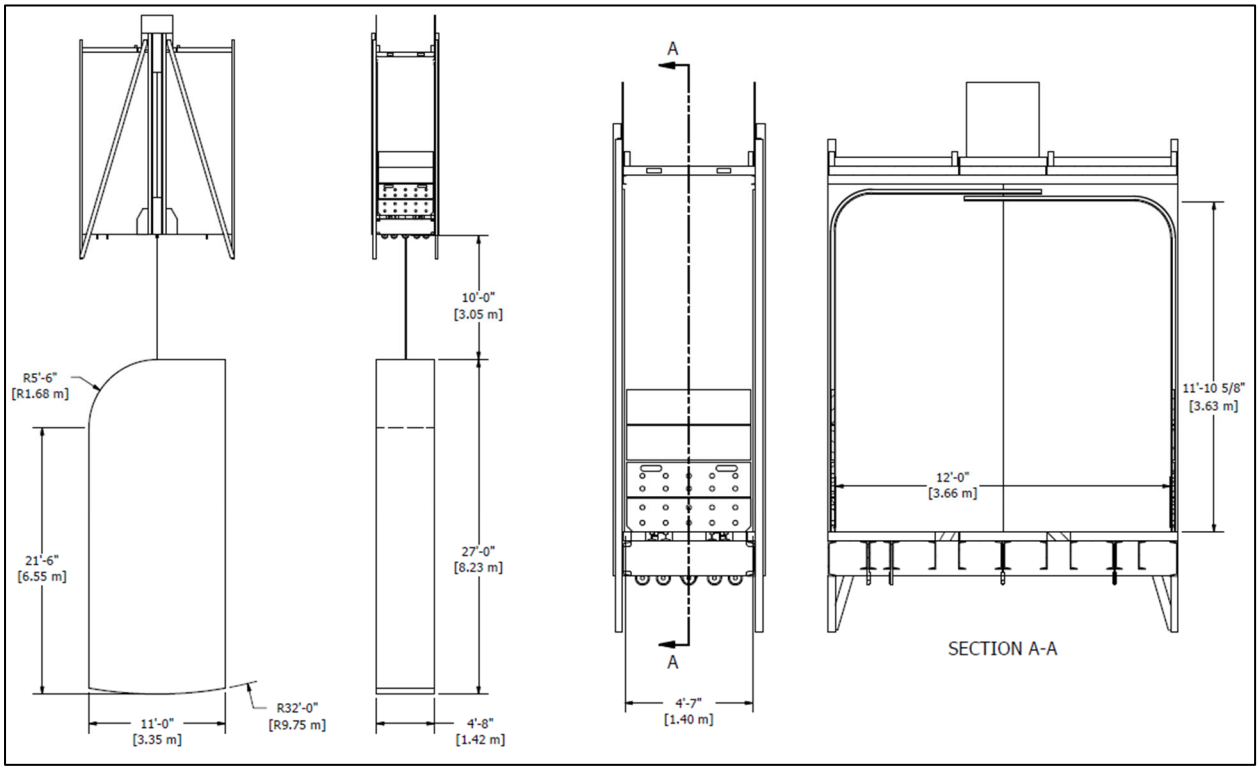


Figure 16: *Ross Cage & under-sling clearance dimensions (standard 10 ft sling)*

Ross Shaft Clearance Standard Sling *(based on cage design dimensions)*

The envelope above shows the following:

1. The longest load that can be slung under the Cage conveyance is 27 ft 0 inches [8.23 m]. At this height of load, the maximum depth of the load is 11 ft [3.35 m].
2. All loads must not exceed 4 ft 8 in [1.42 m] in width. (For slung loads, 2 in [50.8 mm] clearance is required on all sides.)

The main restriction for slung load dimensions in the Ross Shaft Cage compartment is the distance between the bottom of the crash beams in the headframe to the top of the collar concrete. This height/distance is 58 ft 5 ½ inches. [17.82 m]. The only height restriction at the 4850L is the space between the shaft sets which is 17 ft 5 in [5.31 m].

SDSTA insurance requirements dictate that non-SDSTA personnel must remain at a distance of 50 feet from slung load tasks/operations.

2.4 Ross Hoisting Parameters

The following table outlines the Hoist Operating parameters.

Specifications		Ross Shaft (Imperical)			Ross Shaft (Metric)	
		Service Hoist	Production Hoist		Service Hoist	Production Hoist
		Conical DD	Conical DD		Conical DD	Conical DD
	Mass (lbs)	13,500	22,000	Mass (kg)	6123.50	9979.04
Payload	Personnel	38	N/A		38	N/A
Rope weight	lbs/ft	4.44	5.91	kg/m	6.61	8.80
Conveyance mass	Mass (lbs)	8,500	15,500	Mass (kg)	3855.54	7030.69
Number of ropes		1	1		1	1
Rope size *6X30G-SFC IPS U ZZ (RL)*	inch dia	1.625	1.875	mm dia	41.28	47.63
Rope strength	lbs	225,000	282,000	kgs	102,041	127,891
	No of decks	1	N/A		1	N/A
	No of cages	1	N/A		1	N/A
	Height (ft)	11'-10 5/8"	N/A	Height (m)	3.62	N/A
	Width (ft)	4'-7"	N/A	Width (m)	1.40	N/A
Cage inside dimensions	Length (ft)	12'-0"	N/A	Length (m)	3.66	N/A
	Height (ft)	Varies - See	Varies - See Slung	Height (m)	Varies - See	Varies - See
	Width (ft)	Slung Load Spec	Load Spec	Width (m)	Slung Load Spec	Slung Load Spec
Slinging Dimensions under cage	Length (ft)	Section	Section	Length (m)	Section	Section
Slinging capacity at 100 fpm	tons	6.5	consult SURF	tonnes	5.90	consult SURF
Guides		wood	steel		wood	steel
	Length (ft)	5,129	5,129	Length (m)	1,563	1,563
	From	surface	surface		surface	surface
Shaft	To	5000L	5000L		5000L	5000L
Typical set spacing	ft	18	18	m	5.49	5.49
Hoisting speed	ft/min Max	1,000	2,750	m/sec	5.08	13.97
Hoist power rated	HP	1,750	3,500	KW	1,305	2,610
Motor speed	rpm	300	300	rpm	300	300
Skip cycle time (one way)	mins	N/A	1.9	mins	N/A	1.9
Cage travel time (one way)	mins	5	N/A	mins	5	N/A
Cage load/unload time	mins	1	N/A	mins	1	N/A
Cage total time (one way)	mins	6	N/A	mins	6	N/A
Cage total time (return)	mins	11	N/A	mins	11	N/A
Slung load travel time (one way)	mins	48	N/A	mins	48	N/A
Slung load/unload time	mins	15	N/A	mins	15	N/A
Slung load total time (one way)	mins	63	N/A	mins	63	N/A
Slung load total time (return)	mins	68	N/A	mins	68	N/A
Availabilty (after all planned maint)	hours/day	20	20	hours/day	20	20
Production capacity	tons/day	N/A	2,500	tonnes/day	N/A	2,268

Table 2: *Ross Hoisting Parameters*

3.0 Yates Shaft

The Yates Shaft is a timber furnished shaft constructed in the late 1930's. This shaft has two cage compartments, fitted with a cage and work deck pair that operate in counterbalance. The Yates Shaft also contains two skips and skipping compartments, however, the Yates skips are currently being utilized for shaft maintenance and are not planned to be used for muck haul in future lab development.

The timber Yates Shaft requires heavy maintenance and is only available for 11 hours per day, 4 days per week. This roughly equates to an 85% availability on an annual basis. The rest of the time, the shaft is restricted to shaft maintenance personnel access only. Currently, the maintenance in the shaft is on a four-day weekend rotation, every other week, illustrated in Figure 17 below. Access during holidays is advertised on a case-by-case basis and is to be clarified with the SDSTA.

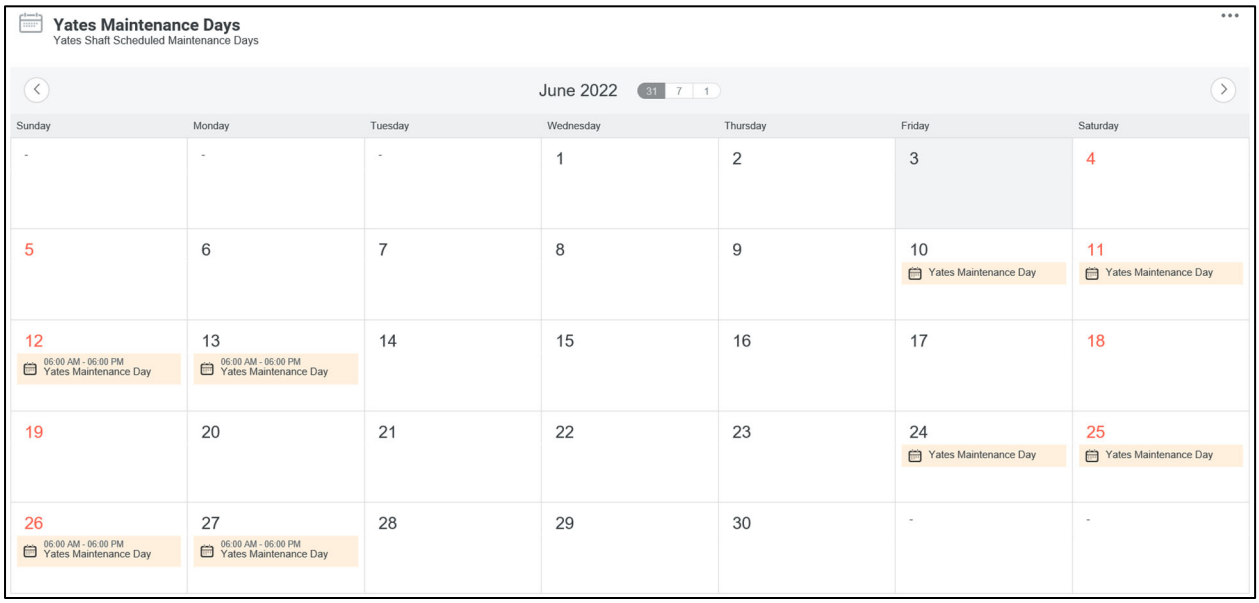


Figure 17: *Yates Shaft maintenance schedule example*

Figure 18 illustrates the typical plan view and compartment cross-section dimensions for the Yates Shaft.

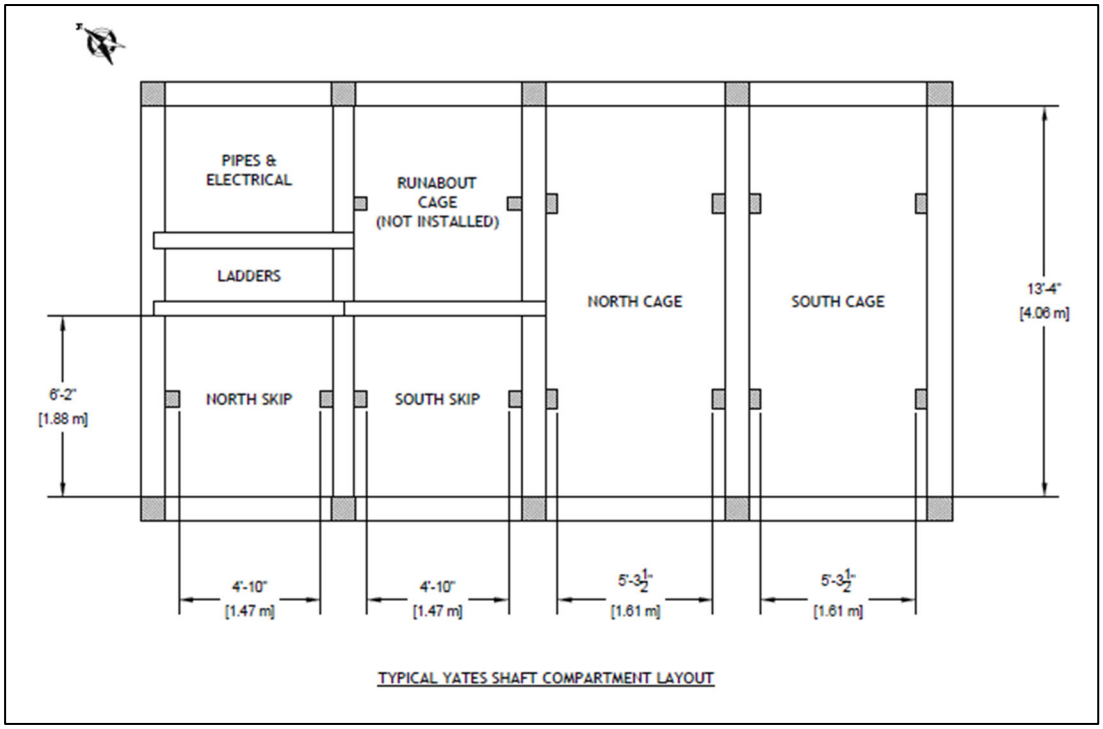


Figure 18: *Yates Shaft plan view typical set*

3.1 Yates Cage Conveyances

The current operating conveyances in the Yates Shaft consist of a cage which operates in the South Cage compartment, a cage work deck which operates in the North Cage Compartment, a South Skip and North Skip. All personnel, material and equipment are currently being serviced through the South Cage. The North Cage work deck is also used for some material and equipment conveyance but is not available for routine manpower conveyance. The North Cage work deck includes load under-sling capabilities, plus is outfitted with a central tower/truss for affixing longer load items such as guides, rail, or drill steel.

Figure 19 *(below)* provides interior dimensions and interference point limits for the South Cage Conveyance.

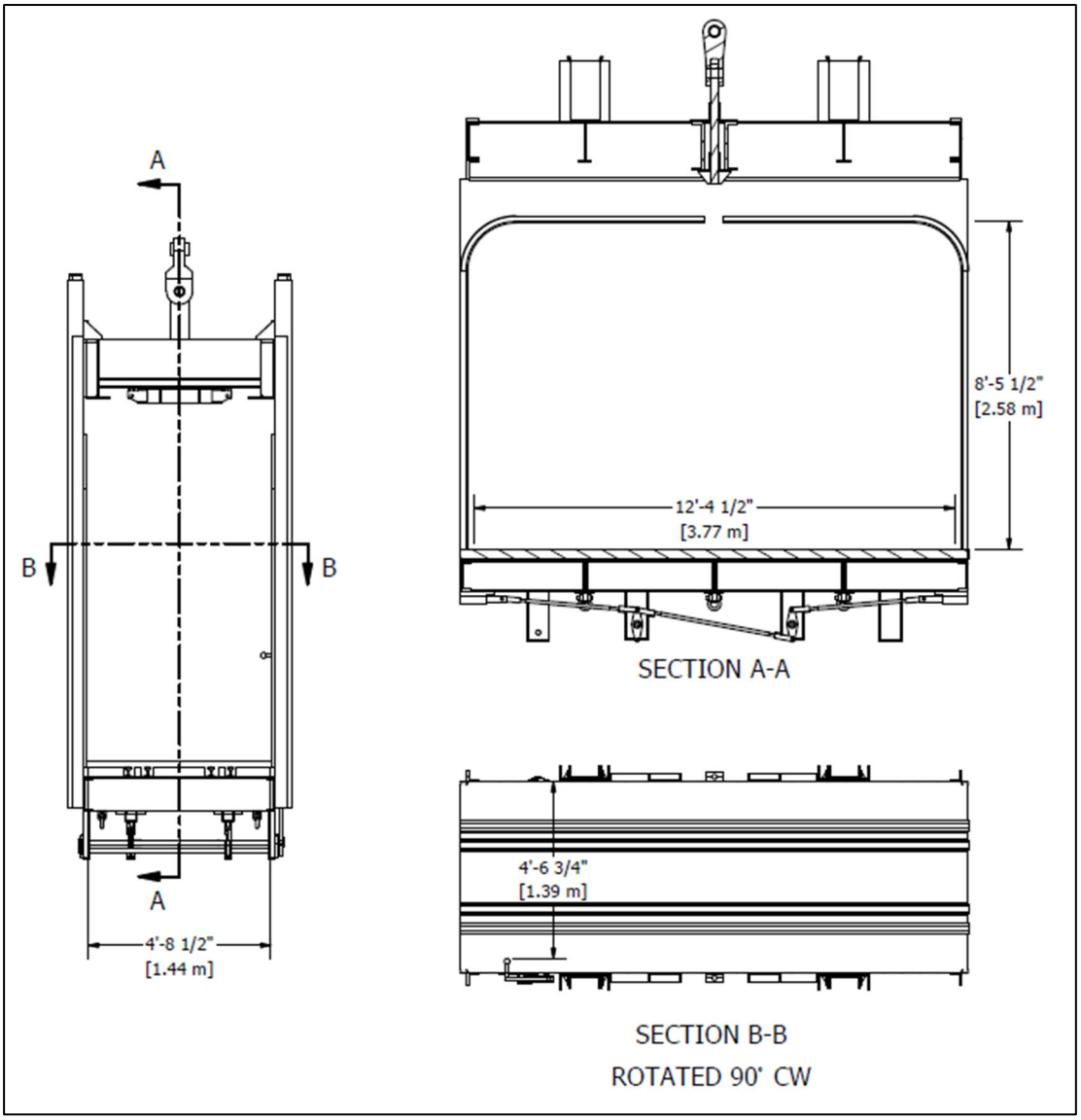


Figure 19: *Yates South Cage dimensions*

Figure 20 *(below)* illustrates the North Cage work deck. Dimensions are shown for the bottom deck only as it is this deck that is used for equipment and materials conveyance.

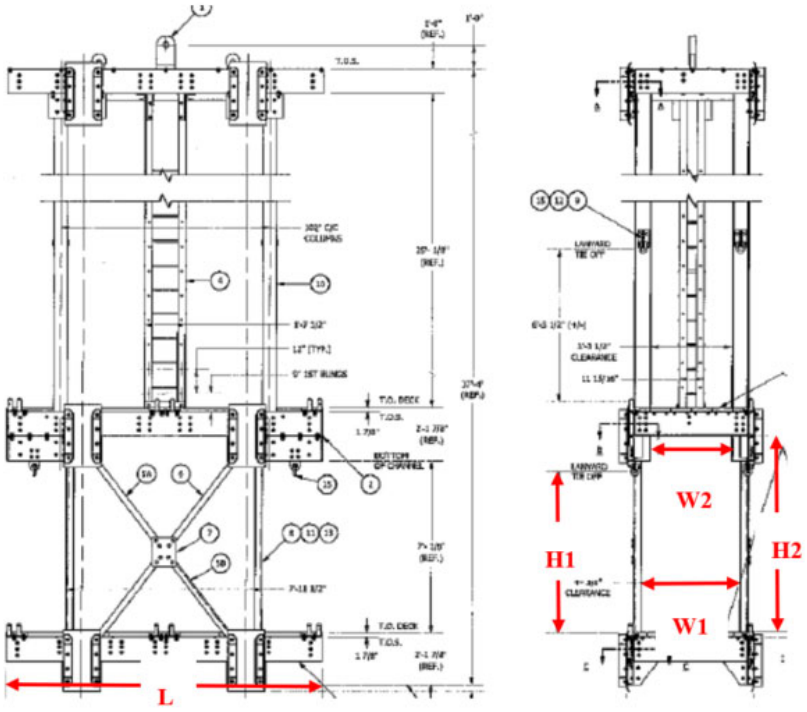


Figure 20: *Yates Shaft North Work Deck*

	Arrangement 1	Arrangement 2
Length (L)	12’ 10” [3.91 m]	12’ 10” [3.91 m]
Height (H)	7’ 0 1/8” [2.14 m]	7’ 11 7/8” [2.44 m]
Width (W)*	4’ 0 3/8” [1.23 m]	3’ 3 ½” [1.00 m]

Table 3: *North Work Deck bottom deck dimensions*

* For loads inside the cage, 1” [25.4 mm] clearance is required on all sides. **The practical operational space in the Yates North Work Deck, bottom deck is therefore 3 ft 1 ½ in wide x 7 ft 9 7/8 in high x 12 ft 8 in long [0.95 m wide x 2.38 m high x 3.86 m long].**

3.2 Yates Shaft Stations

The Yates Shaft Stations that are anticipated to have laboratory traffic are the 800L, 1700L, 4100L and the 4850L. Given the 4850L has the highest level of traffic, specific load handling considerations and information is provided herein, with the other listed levels requiring more investigation by the experiment/client prior to handling loads.

It is important to analyze components traveling to the 4850L as well as components travelling through the 4850L where different obstacles arise. Figure 21 depicts details of the 4850L near the Yates Shaft Station.

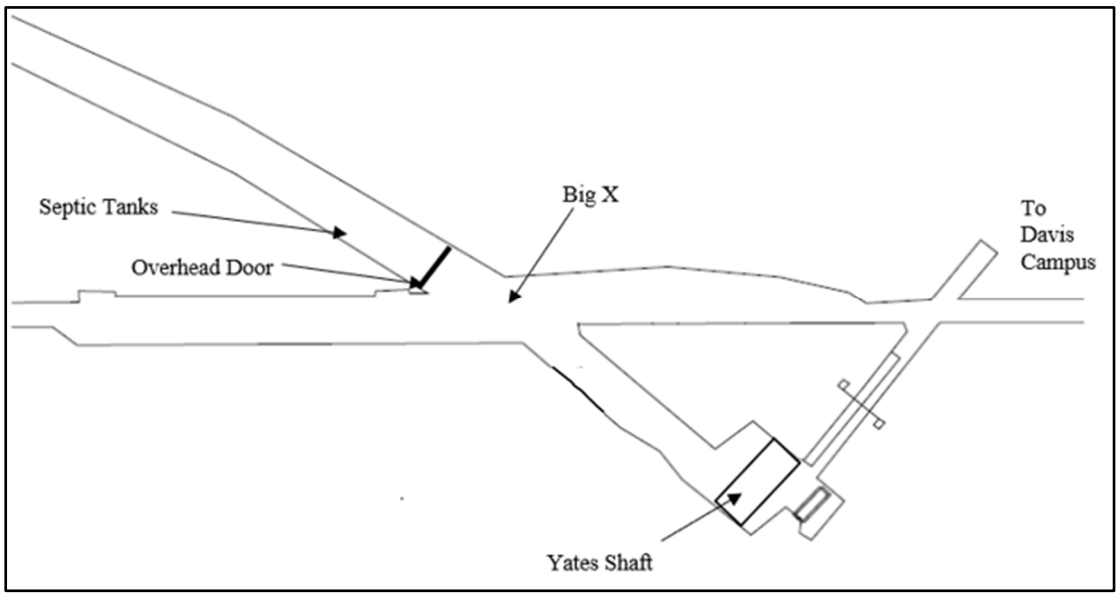


Figure 21: *Plan view at 4850L Yates Shaft Station*

The lowest clearance occurs at the Big X intersection where there is a utility hanger that supports ductwork for the Davis Campus. The clearance at this location is 94 in [2.39 m]; see Figure 22. Given that an object is expected to be loaded on a rail flat car that is 18 in [457.2 mm] high, the maximum height of any load going under the duct hanger is 94 – 18 = 76 in [2387.60 mm – 457.20 mm = 1930.40 mm].

Figure 23 illustrates the 4850L brow/back height restrictions at the cage unloading point.

Table 4: Depicts the height restrictions at the 4850L Yates Shaft Station using different vehicles under the load.

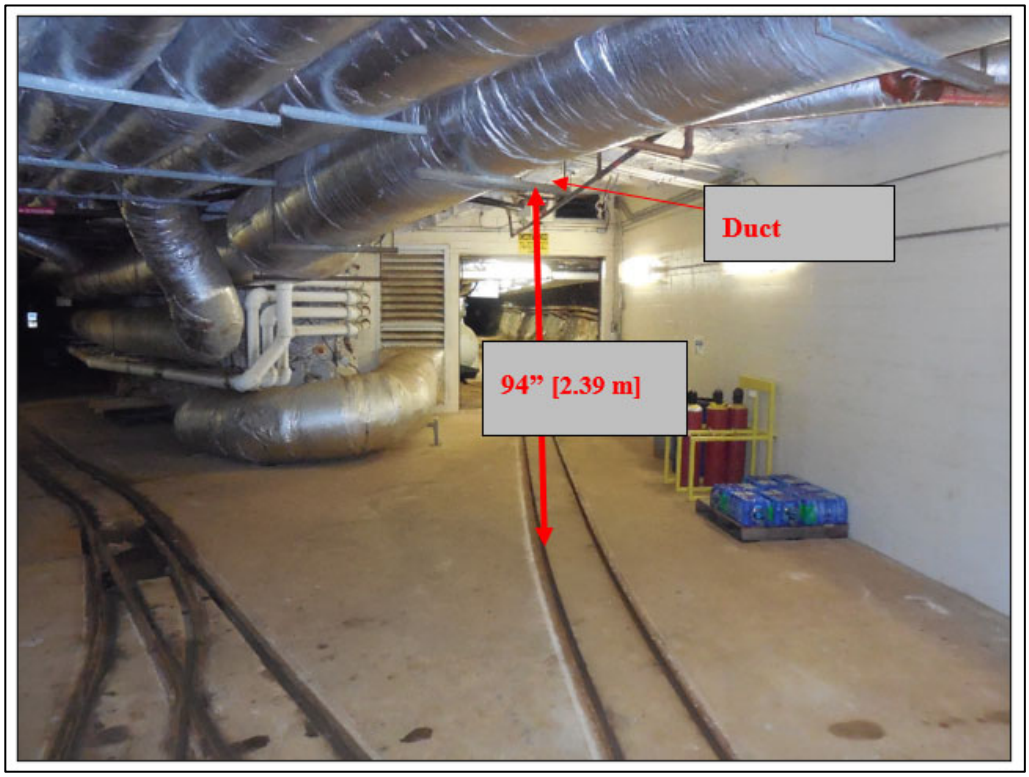


Figure 22: *Lowest clearance at the Yates Shaft Station*

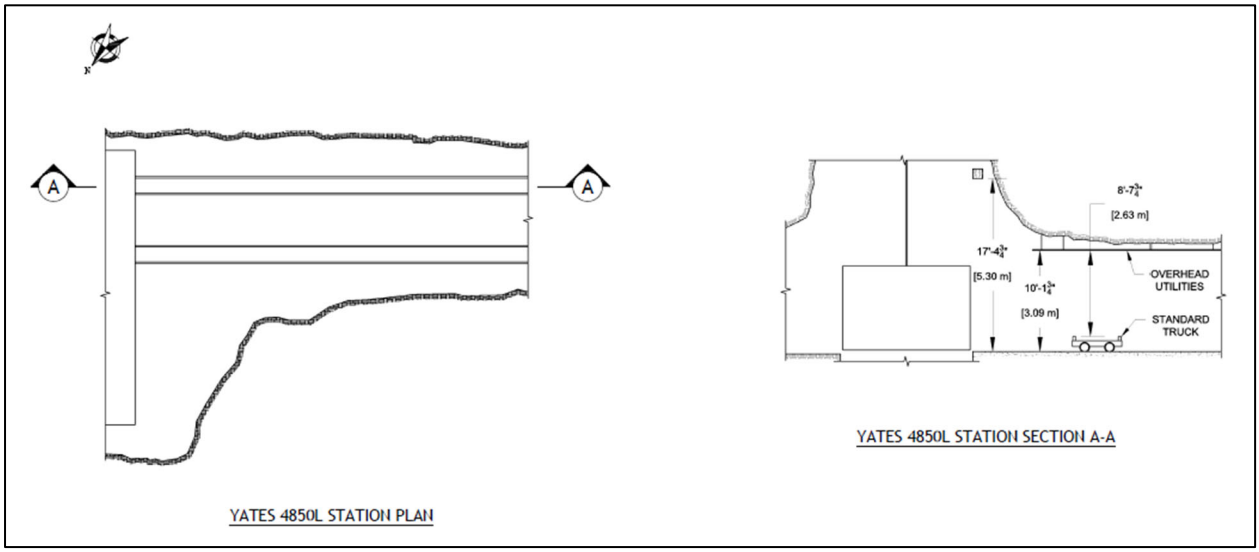


Figure 23: *4850L brow clearance at the Yates Shaft Station*

Means of moving component into cage	Required Clearance		Max height of component	
	in	*mm*	*Ft*	*Mm*
Dragging or use of skid plate	0 - ¼	0 - 6.35	8' 5 ½"	2578
Air Bearing	1 ½	38.1	8' 4"	2540
Lowboy or Rail Cart	8	203.2	7' 9 ½"	2375
Standard Car	18	457.2	6' 11 ½"	2121

Table 4: *Yates 4850L Shaft Station clearance dimensions versus load conveyance vehicle*

Three other Yates Shaft Stations that may have laboratory load traffic are the 800L, 1700L and the 4100L. Note the 800L is foot traffic only on the Yates side given legacy equipment obstructions and no rail capabilities. The 800L is therefore not illustrated in the following figures. Figures 24 and 25 illustrate the brow/drift clearances with respect to the cage for the 1700L and 4100L respectively.

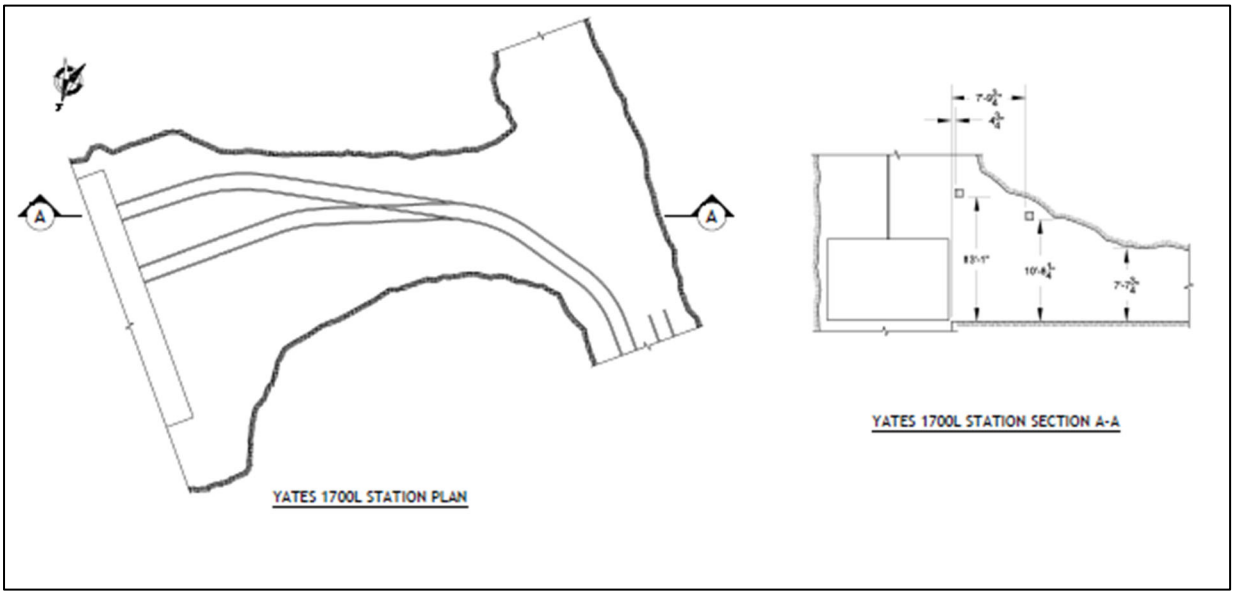


Figure 24: *1700L Yates Station*

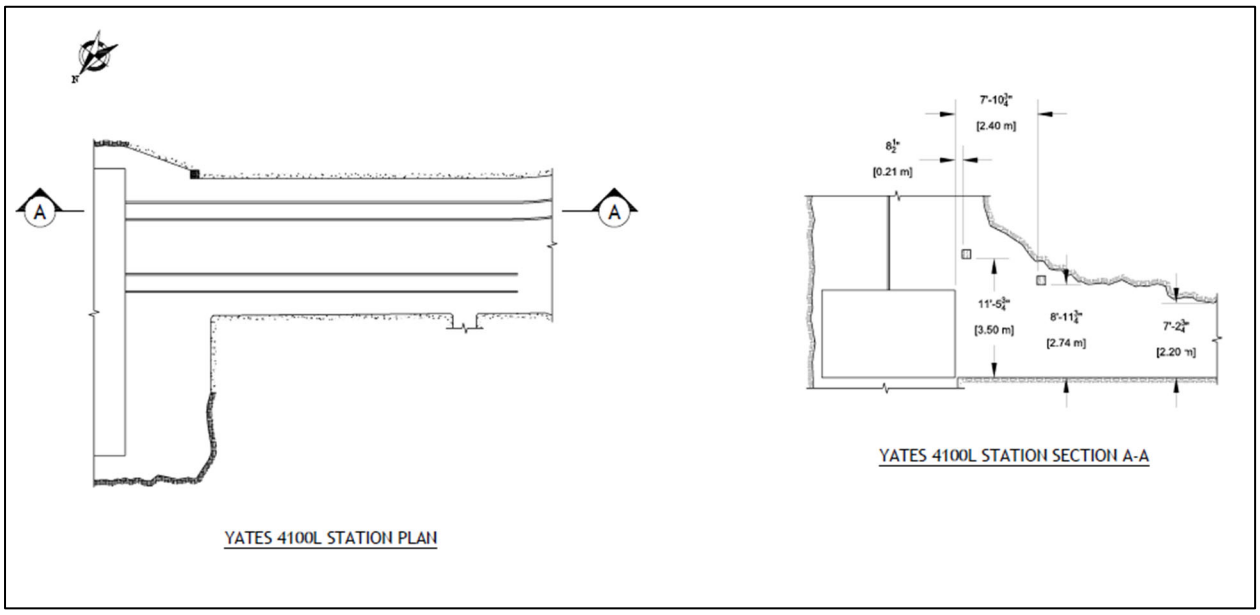


Figure 25: *4100L Yates Station*

3.3 Yates Slung Loads

In the Yates Shaft, there is opportunity to sling loads under both cages, however the South Cage is preferred due to alignment at most underground stations. An analysis has been performed on slung load limitations. The slung load is attached to the center of the bottom of the conveyance for stability purposes as shown in the schematics (Figures 26 & 27) below:

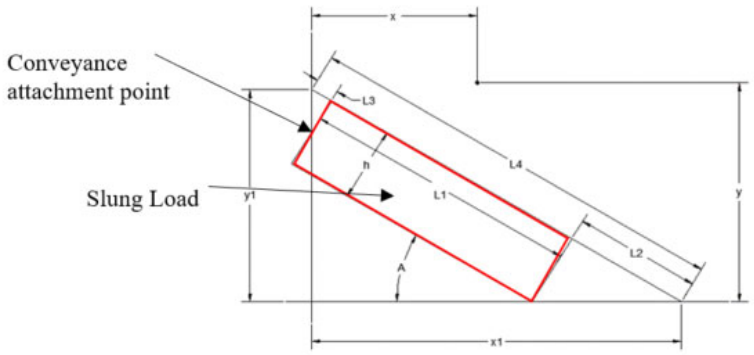
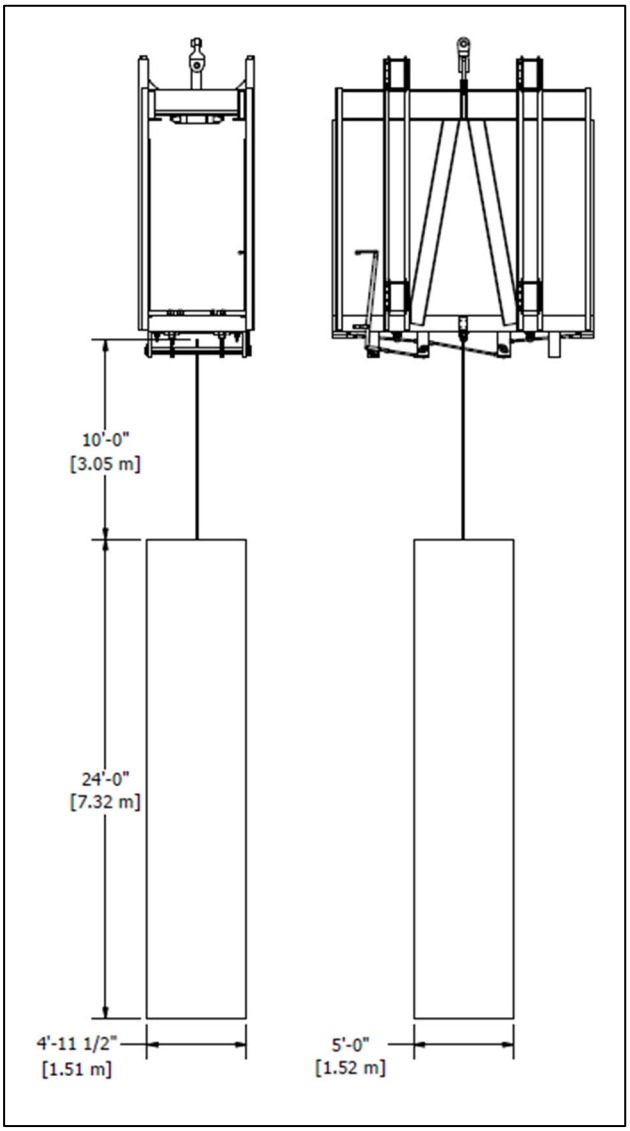


Figure 26: *Yates Shaft slung load parameters*

Factors that are considered in determining slung load parameters include the following:

1. The load needs to fit within the space available in the compartment with a 2 in [50.8 mm] clearance on all sides. Refer to Figure 18.
2. There needs to be enough space under the conveyance when the cage is at its highest location in the head frame for the load to be pulled into the compartment from the shaft collar.

3. There needs to be enough space at the unloading location (underground station) for the load to be pulled out of the compartment and on to the level.
4. When lowering a slung load, the travel speed needs to be greatly reduced to ensure that the load does not swing into shaft infrastructure. This can be somewhat controlled in special situations by installing guide shoes on the load. However, this process adds considerable time to the conveying process. Typical travel speeds for slung loads are limited to about 100 feet per minute [0.762 m/s].
5. For the South Cage, the maximum weight of the slung load is 10,000 lbs [4,536 kg].
6. Slung load plans are to be reviewed/approved through SDSTA Operations prior to implementation.



Note: 5'-0" max depth limit depicted for a 24'-0" max long load.

Figure 27: *Yates South Cage under-sling clearance dimensions (standard 10 foot sling)*

3.4 Yates Hoisting Parameters

Specifications		Yates Shaft (Imperical)			Yates Shaft (Metric)	
		South Cage	North Work Deck		South Cage	North Work Deck
		Conical DD	Conical DD		Conical DD	Conical DD
Payload	Mass (lbs)	10,600	3,000 lbs top deck 4,000 lbs bottom deck	Mass (kg)	4808	1,119 kgs top deck 1,493 kgs bottom deck
	Personnel	30	16		30	16
Rope weight	lbs/ft	5.91	5.91	kg/m	8.79	8.79
Conveyance mass	Mass (lbs)	12,800	14,300	Mass (kg)	5,805	6,485
Number of ropes		1	1		1	1
Rope size	inch dia	1.875	1.875	mm dia	47.63	47.63
Rope strength	lbs	338,000	338,000	kgs	153,317	153,317
	No of decks	1	2		1	2
	No of cages	1	1		1	1
	Height (ft)	8'-5 1/2"	N/A	Height (m)	2.58	N/A
	Width (ft)	4'-6 3/4"	N/A	Width (m)	1.39	N/A
Cage inside dimensions	Length (ft)	12'-4 1/2"	N/A	Length (m)	3.77	N/A
	Height (ft)	Varies - See		Height (m)	Varies - See	
	Width (ft)	Slung Load Spec	Varies per deck	Width (m)	Slung Load Spec	Varies per deck
Slinging Dimensions under cage	Length (ft)	Section	See Dwg	Length (m)	Section	See Dwg
Slinging capacity at 100 fpm	tons	5	5	tonnes	4.54	4.54
Guides		wood	wood		wood	wood
	Length (ft)	4,934	4,934	Length (m)	1,504	1,504
	From	surface	surface		surface	surface
Shaft	To	4850L	4850L		4850L	4850L
Typical set spacing	ft	6	6	m	1.83	1.83
Hoisting speed	ft/min	500-800	500-800	m/sec	2.54-4.06	2.54-4.06
Hoist power rated	HP	2,500	2,500	KW	1,865	1,865
Motor speed	rpm	360	360	rpm	360	360
Skip cycle time (one way)	mins	N/A	N/A	mins	N/A	N/A
Cage travel time (one way)	mins	10	10	mins	10	10
Cage load/unload time	mins	5	5	mins	5	5
Cage total time (one way)	mins	15	15	mins	15	15
Cage total time (return)	mins	30	30	mins	30	30
Slung load travel time (one way)	mins	48	48	mins	48	48
Slung load/unload time	mins	15	15	mins	15	15
Slung load total time (one way)	mins	63	63	mins	63	63
Slung load total time (return)	mins	78	78	mins	78	78
Availabilty (after all planned maint)	hours/day	11hr/day, 4 days/wk	11hr/day, 4 days/wk	hours/day	11hr/day, 4 days/wk	11hr/day, 4 days/wk
Production capacity	tons/day	N/A	N/A	tonnes/day	N/A	N/A

Table 5: *Yates Hoisting Parameters*

4.0 Additional Potential Conveying & Transport Scenarios

Further analysis and engineering may result in expanded load dimension opportunities for both the Ross and Yates Shafts conveyances. The following areas can be further investigated:

1. Utilization of space between shaft dividers rather than guides for special loads. This may be possible for circular loads that could be located between guides in the Yates Shaft, increasing the maximum width up to 4 in [101.6 mm]. This specific load case was used for LUX-ZEPLIN (LZ).
2. Design of pivotal slings for loads suspended below the cages. These slings could be designed to attach to the side of the loads rather than the top of the load which would enable the top of the load to rotate out towards the back of the shaft, rather than at the center. The graphic below shows this:

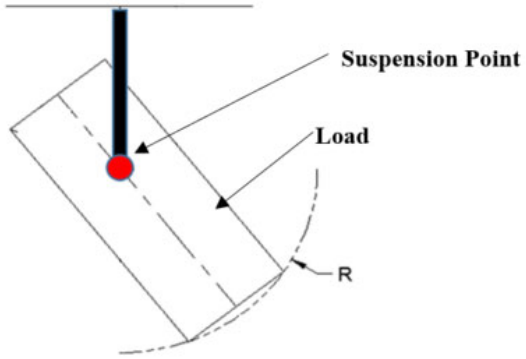


Figure 28: *Alternate sling load scenarios*
Contact the SDSTA Engineering Department to pursue any of these scenarios

4.1 Ross North & South Skip Compartment Loads

The North and South skip compartments at the Ross Shaft will be used for long, narrow components that cannot utilize a standard or special sling. If it is desired to use the skip compartments, the SDSTA should be consulted due to the complexity involved with loading components into the shaft.

4.2 Available Rail Car Dimensions – Load Transport on Levels by Rail

The 4850L (and most other levels at SURF) are typically outfitted with rail to facilitate transport of loads using a rail car – electric locomotive combination. The most widely used rail cars are flat-deck style, and Figures 29 and 30 depict the typical dimensions for the available fleet. Granby rail cars (dump-type tub) are also available for transport of rock or earthen materials (not illustrated, contact SDSTA for details).

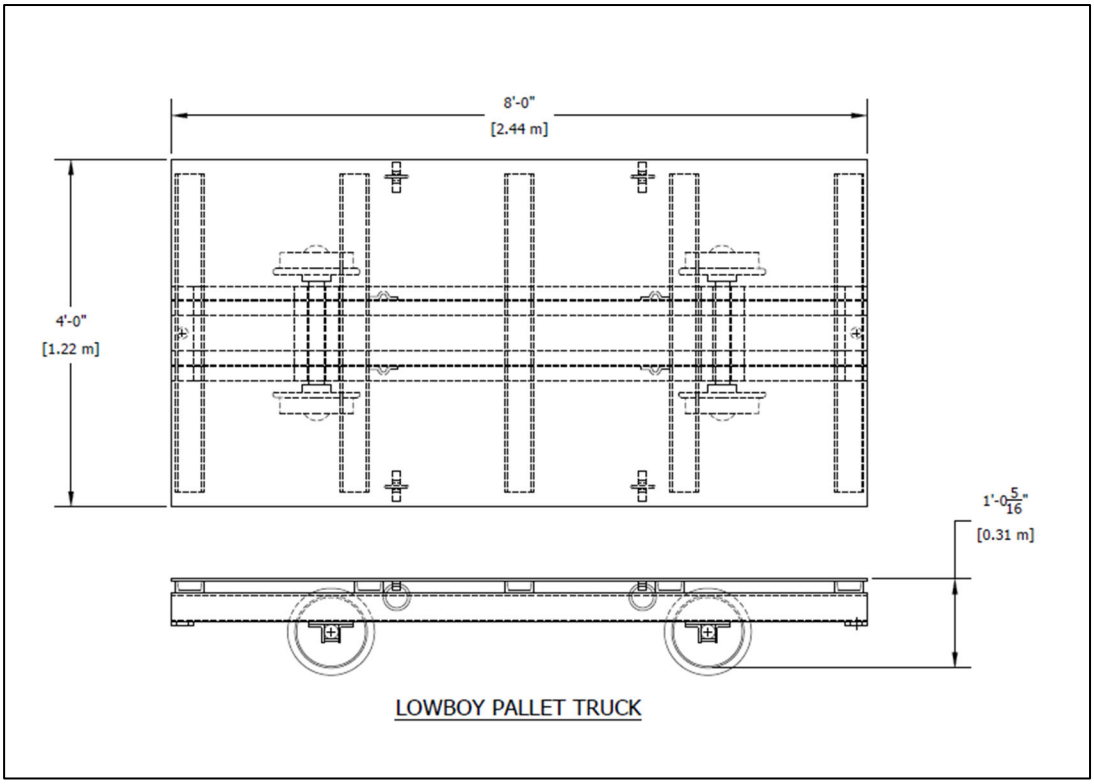


Figure 29: *Lowboy flat deck rail car (Lowboy Pallet Truck)*

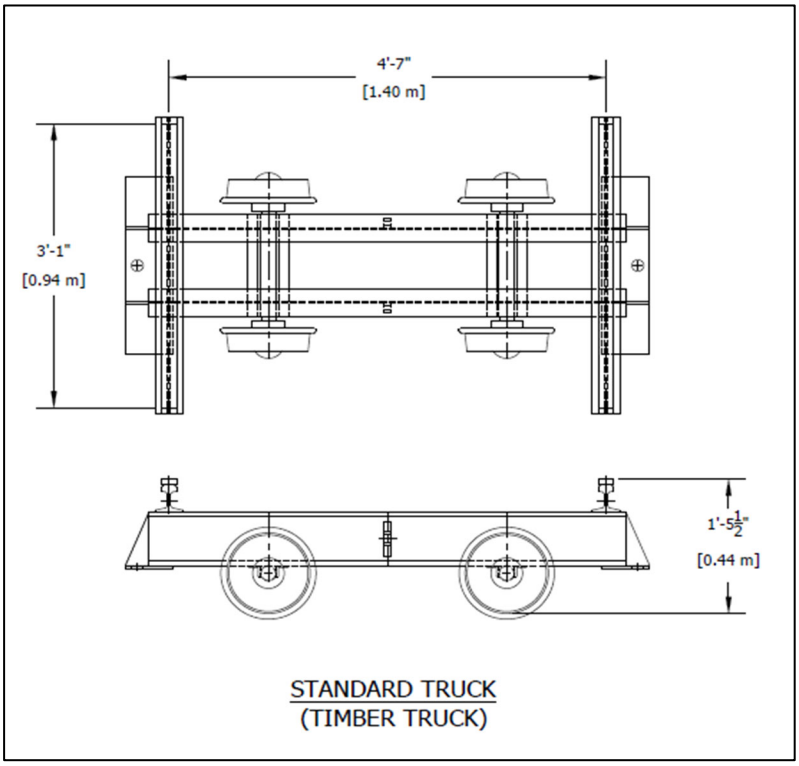


Figure 30: *Standard flat deck rail car (Timber Truck)*

4.3 Conveyance Restrictions at the 4850L

In addition to shaft and shaft station restrictions previously discussed in this document, restrictions exist along the various horizontal travel ways located on the 4850L. The map below shows locations of various doors that need to be considered when planning the horizontal transportation of materials and equipment:

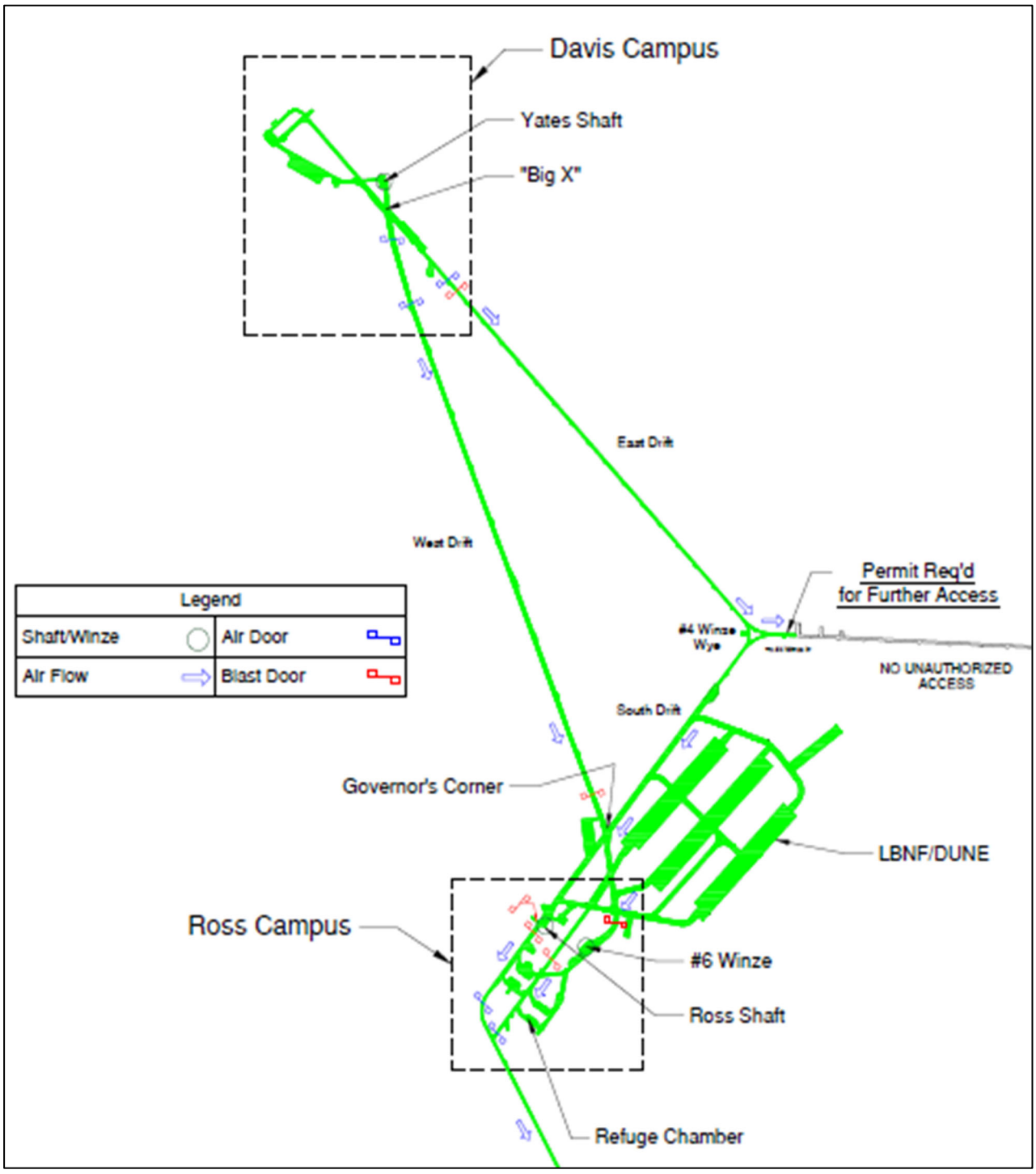


Figure 31: *Map view of conveyance restrictions on the 4850L – September 2022*

5.0 Additional Reference Drawings

The following drawings were used in the slung load analysis for the Ross and Yates Shafts. They are provided here **for reference only**.

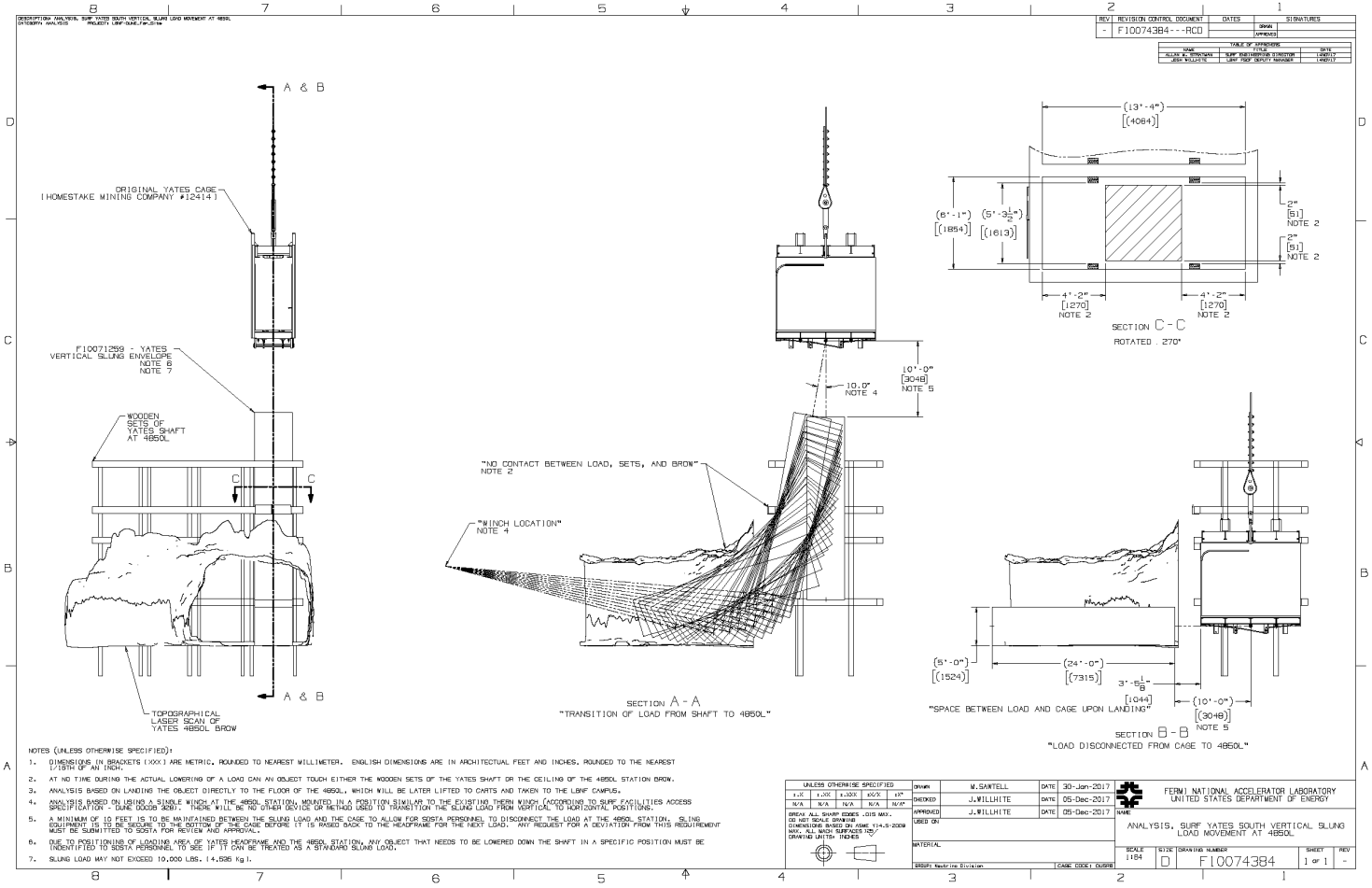


Figure 32: *Yates South Cage vertical slung load analysis at the 4850L*

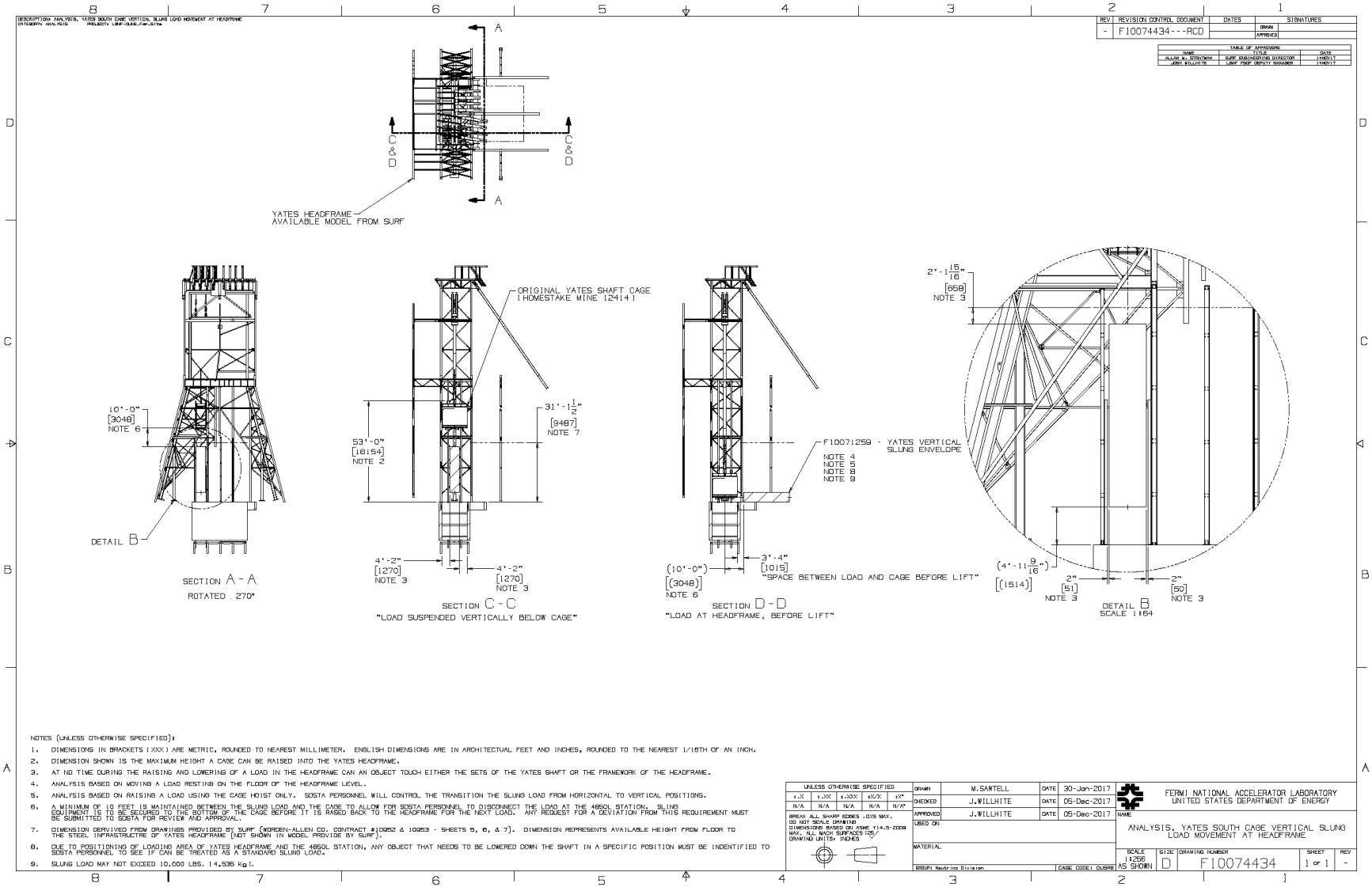


Figure 33: *Yates South Cage vertical slung load analysis*

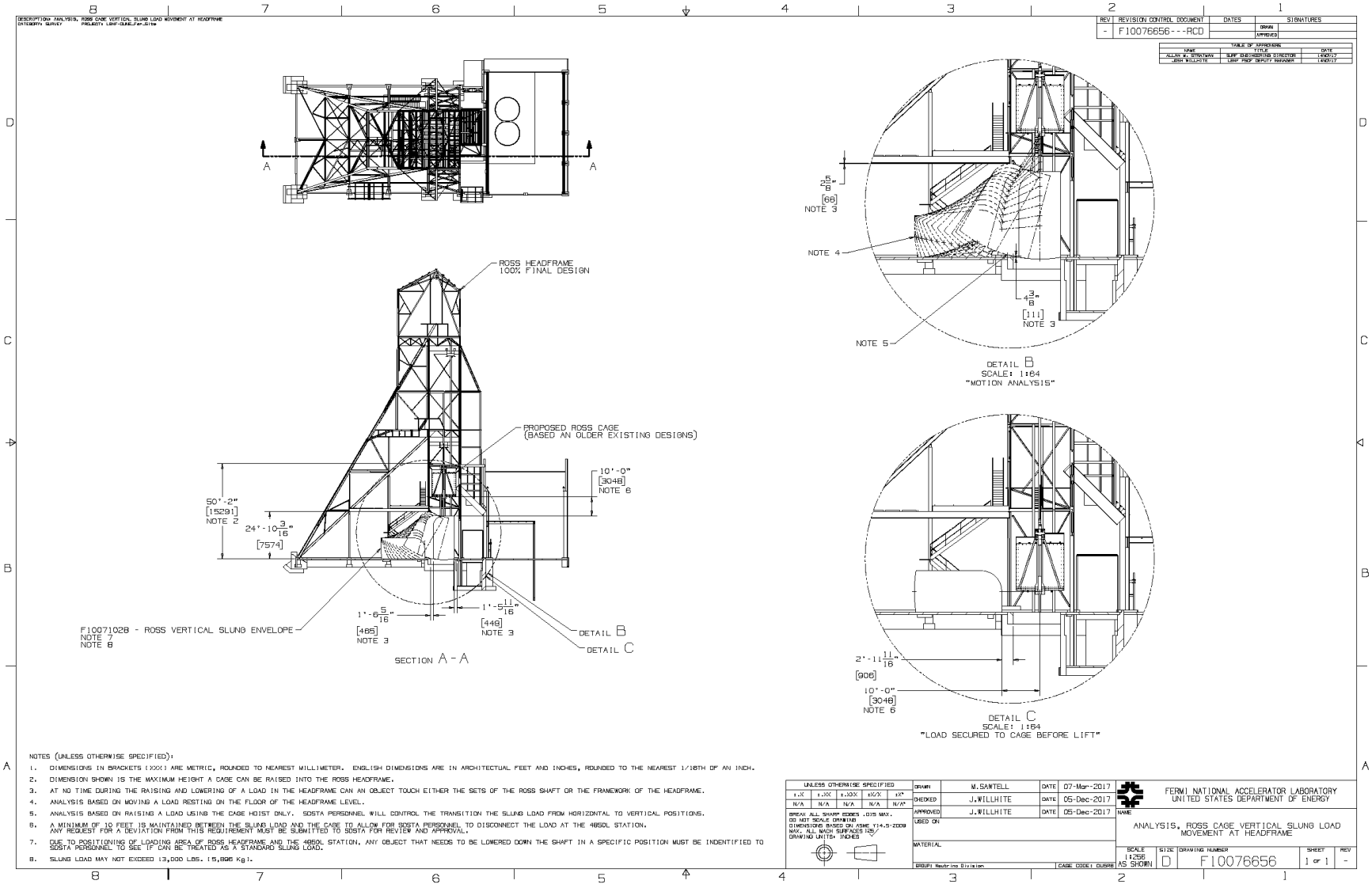


Figure 34: *Ross Cage vertical slung load analysis*

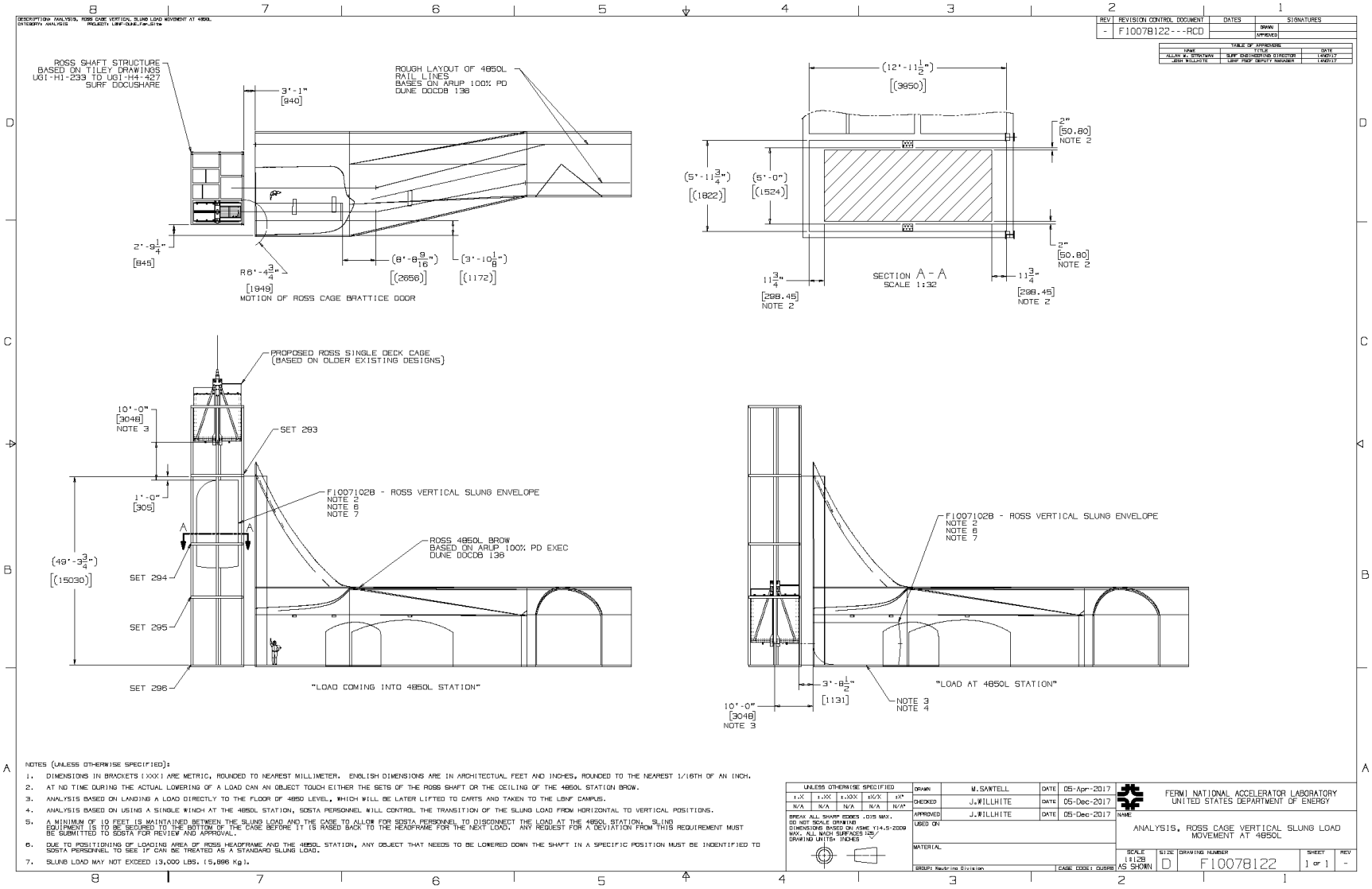


Figure 35: *Ross Cage vertical slung load analysis at the 4850L*

Revision History

Rev	Date	Section	Paragraph	Summary of Change	Authorized by
01	9/28/2022	NA	NA	Initial Release	CCR 631
02	5/29/2024	NA	NA	Update Logo	CCR 946